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A MODEL FOR EVALUATING VENDOR
PROPOSALS FOR PRICE AND LEAD TIME

by

Arthur B. Horsley

December, 1993

Principal Advisor: Alan W. McMasters

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A Model for Evaluating
Vendor Proposals for Price and Lead time

by

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

This thesis presents a personal-computer model which can be used for comparison of vendor proposals for hardware items. It calculates the expected (or average) total annual costs associated with ordering, holding, and backordering as well as the procurement costs to meet the expected annual demand for the item. It was developed for the Navy's Rapid Acquisition of Manufactured Parts (RAMP) Program Office to demonstrate the cost savings associated with shorter production lead times. This thesis provides the mathematical development of the model, based on the Navy's wholesale level consumable item model, and a user's guide. The software is designed to run on LOTUS 123 or equivalent applications.

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I. INTRODUCTION

A. BACKGROUND

The Rapid Acquisition of Manufactured Parts (RAMP) Program Office was established by the Naval Supply Systems Command in 1989 to investigate the possibility of having a government source for the fabrication of complex machined parts and also the capability of providing these components within very short production lead times. The latter can be accomplished through the use of Computer Integrated Manufacturing (CIM) techniques. Data packages for parts likely to become RAMP candidates are programmed so that the part can be produced on Numerical Controlled (NC) machines. A major advantage of this process is that, after being programmed, parts production will require very little set up time and no operator training.

The RAMP program is headquartered in Arlington, Virginia and has industrial sites located in Cherry Point, North Carolina, Norfolk, Virginia, Crane, Indiana, Charleston, South Carolina, and Pensacola, Florida. Each site has different capabilities but, while no two activities are identical, some may share the capability to manufacture certain items. Each site evaluates Requests for Quotes (RFQs) and, if capable of producing the item, provides a quote to the Program Office which includes both price and production lead time. There is

competition between RAMP and the private sector as well as competition between different RAMP sites having overlapping capabilities.

There are several reasons why an item may be referred to the RAMP Program Office. Examples include:

1. The item may be required in quantities that are insufficient to attract bids from competent vendors at a reasonable price.

2. The item may be urgently required and the usual sources of supply cannot provide assets rapidly enough.

3. The item may be referred as a routine source of supply. If production by a RAMP site is warranted, the Program Office will refer the production of the item to one of its sites.

Most items produced by RAMP must have their original drawings converted to the proper computer format compatible with the NC machines. This effort accounts for a considerable portion of the cost differential between RAMP and traditional machine shops. However, these computerized instructions have an indefinite life span, adding value to the original data package. Once the programming has been done there will be minimal set-up costs for a production run and the production costs will be low.

One current problem is how to pay for the programming (reverse engineering of drawings in most cases) without having the first lot's unit cost being very high. The allocation of the programming cost is a problem because without the

assurance of subsequent awards for an item there can be no amortization of the initial set up costs. (RAMP interview, August 1993). However, further consideration of this problem suggests that it is not appropriate to include the programming costs in the bidding process. These costs can be recovered instead from future savings in the Navy Stock Fund. This is accomplished by reducing the reorder point of an item as a consequence of shortening the production lead time.

Another difficulty arises in the evaluation of proposals by procurement personnel using data provided by the item inventory manager, and the comparison with the other offerors of the benefits of rapid production at a RAMP site. It is a simple matter to determine the vendor with the lowest unit cost, even with price breaks for increased production lot quantities. It is far more difficult to affix a cost to long production lead times and the increased probability of stockouts endured prior to delivery of the product. The RAMP program has managers at both ICPs (SPCC and ASO) to help address this problem. Their task is to assist individual item inventory managers in determining the value-added in manufacturing the parts at a RAMP site.

Because of the nature of the RAMP program, variability in proposed production lead times between RAMP sites and non-RAMP bidders can be very great. In particular, extremely high lead times can occur if a non-RAMP bidder has not made the item in the past. RAMP production lead times are dramatically lower

despite the initial efforts required to program the production instructions for an item. Without the aid of an efficient model to compare the expected total annual inventory management costs associated with the particular procurement (i.e., the costs to the vendor as well as the costs of ordering, holding, and backordering), it is difficult to justify the procurement of the item from anyone other than the lowest bidder.

The current model, FCIM-DSS, was developed by the Fleet Material Support Office (FMSO) in an effort to assess the cost advantage of rapid delivery of required items. It was deemed unsatisfactory by RAMP personnel because it appeared to lack sensitivity to the length of procurement lead time. Another reason it was unacceptable was that it used conventionally generated backorder cost values which, in the case of most RAMP candidates, understated the cost penalty associated with the prolonged backorder time of an item.

In contrast, the model described in this thesis is very sensitive to procurement lead time and it includes an annual cost per unit of an item backordered, based on the desired service level determined by the item inventory manager. This service level is typically defined in terms of the probability that a demand will be met immediately from stock during the time between when an order is initiated for more units and when that order is received into stock (i.e., procurement lead time).

RAMP, like other sources of supply, must show that it provides the best value to the customer. The fact that it is a government entity does not entitle it to special consideration under procurement regulations. The important measure for any vendor should be that it provides the best value, not just the lowest unit cost. Best value for purposes of this thesis is the minimization of all relevant inventory management costs from the time of order initiation to the time of issue of the material to the end user.

B. PURPOSE

The purpose of this thesis is to present a mathematical model which can be used on a personal computer for evaluating vendor proposals for materials purchased by government agencies. This model was developed under the sponsorship of the RAMP Program Office. The model is designed specifically for use by the sponsor, but has broad general application throughout the government procurement arena as well.

The model, known as the **Best Value Model,** was developed to emphasize how inventory management costs are influenced by the unit price and production lead time of each vendor's proposal. It looks forward, calculating the expected total annual costs in terms of ordering, holding, backordering, and procurement costs for each bid. In addition, it allows for consideration of quantity discounts. Finally, and most importantly, it insures the evaluation of each proposal at the service level

desired by the inventory manager for that item at the time it is ordered.

The model was designed for maximum utility in terms of ease of operation and speed. It is targeted for use at the GS 5,7, and 9 levels, requiring only basic computer skills and approximately one minute per bid in terms of processing time. The output is a pre-formatted bid evaluation worksheet (Appendix A) which can be included in the procurement documentation file for source selection justification.

This model requires that the item manager deviate slightly from the usual methodology used in the Uniform Inventory Control Point (UICP) consumables model for determining the reorder point and order quantity. The item inventory manager will now be required to determine the proper service level for a particular item rather than it being determined by the parameters of the problem.

C. SCOPE

There are four different situations in which RAMP may be employed. Items may be referred for reasons of national security, special one-time procurements, system phase-outs and other instances of sharply declining demand, and as an economical source of supply for steady-state demand items. The first three are not addressed in this thesis for the following reasons:

1. Items urgently needed in the interests of national security. RAMP has little competition in this area. When relieved of the burden of normal administrative procurement procedures, finished products can be available for shipment within days in many cases. The ability to determine the value to the government of these emergency procurements would be useful, albeit extremely hard to quantify. In situations such as these, the expected total annual costs of inventory management is not an appropriate measure of effectiveness.

2. Other one-time procurements. (Not including Life-of-Type procurements). These are procurements which are needed to satisfy immediate stockout conditions or to adjust the reorder point in anticipation of a procurement from a vendor specializing in providing that item at a lower cost, but with a longer production lead time. These items are generally low-cost (and, therefore, have low carrying costs), high-demand items of a high priority nature, whose on-hand balances have fallen to an unusually low level. While such short-term urgent demands could be satisfied by RAMP, it would be uneconomical to provide continuing production at a RAMP site.

It should also be mentioned that items which are simple in design (few machining operations per unit) and can be manufactured inexpensively by less sophisticated machinery should not be manufactured by RAMP sites except in the case of category 1 above (RAMP interview August, 1993).

3. Sharply declining demand. The model discussed in this thesis is not designed for other than steady-state demand items. Production by RAMP of items which have sharply declining demand forecasts, however, is appropriate. The small lot sizes afforded by RAMP accommodate the large variability in demand, reducing the need for excessive safety stock. The ability to reconstitute production capability using computerized instructions also greatly reduces set-up costs. A model to determine the appropriate lot size based on demand trend or other such measures is a fertile area for further research. A particularly interesting aspect of this category would be the life-of-type procurement scenario, as the ability to rapidly produce lot sizes approaching single units can compensate for forecasting errors in terms of quantities required to satisfy demand towards the end of an item's life cycle.

D. METHODOLOGY

The major sources of reference information used in this thesis were personal interviews with program office and ICP representatives, library research, and lecture notes. A model was then developed which is designed to use system parameters provided by an item inventory manager and determines, using generally accepted analytical methods, the procurement source having the best value in terms of lowest expected total annual inventory management costs.

The model itself is based on two existing models; namely, the UICP consumables model (NAVSUP Publication 553, 1983) and Q Star (Project Q Star, 1985), both of which attempt to minimize the expected total inventory management costs through selection of the optimal reorder point and reorder quantity.

The most significant difference between this model and the UICP model is the determination of the shortage cost multiplier, known as lambda (λ). The UICP consumables model employs a fixed lambda value (dollar amount) for all items in a four-digit cognizance management group. This value is used as the estimated cost of a requisition on backorder for a year, regardless of requisition quantity or urgency of demand. Its value is derived by establishing a service level goal for the cognizance group. That service level is the desired average number of requisitions which should be filled per year from stock on hand. The model derived in this thesis determines the value for lambda which would give a different desired service level, namely, the probability of a stockout during procurement lead time. Thus, this lambda value is the Inventory Manager's *implied* cost of a backordered demand occurring during procurement lead time.

The model is not radical in nature, and does not require a major departure from established procedures currently in place in the Navy's wholesale inventory system.

E. DELIVERABLES

Accompanying the text of the thesis is a copy of the model, which is in LOTUS format, along with a user's guide describing how to operate the program. Because the model's determination of optimal order quantities and reorder points is iterative in nature, the operation of the program is slightly more complicated than most spreadsheet programs. If adopted, the program can be reproduced outside of a spreadsheet program by either a computer science thesis student or contractor, who can integrate the iterative process into an automatic routine, using computer programming languages such as Fortran or PASCAL.

The prototype model remains to be validated and accepted by the Naval Supply Systems Command (NAVSUP). This will require applying it to a variety of situations and demonstrating its ease of use to inventory managers and procurement personnel.

F. PREVIEW

Chapters II and III describe the mathematical basis of the calculations used by the model. Chapters IV describes the model itself, and provide operating instructions and procedures relating to bid analysis. Chapter V is an example problem. Chapter VI presents a summary of the thesis, conclusions drawn from the analyses, and recommendations for the RAMP program office.

II. DERIVATION OF THE VENDOR EVALUATION MODEL

A. OVERVIEW

This model generates an expected total annual cost for any combination of purchase price and procurement lead time. Because of the low demand nature of most RAMP candidates, the Poisson distribution seems appropriate. The UICP model's structure is used in this model. Its derivation is based on the Hadley and Whitin exact backorders model (Hadley and Whitin, 1963) when demand is described by the Poisson distribution.

There are four components to the expected total annual costs formula. The first is the expected annual costs associated with placing an order. Included in this ordering cost component are the costs of preparing the delivery orders which are issued when inventory position reaches the reorder point, the initial contracting costs, and the transportation costs to deliver the finished order to a stock point. The second are the average annual costs of holding inventory of an item. The third is the *implied* expected annual costs of backorders. The fourth is the expected total item procurement costs for a year. Each of these components is discussed in detail in the next several sections of this chapter. The

discussion includes the mathematical formulation of the values, and the reasoning behind the assignment of the costs.

B. ORDERING COSTS

The first costs to be considered are the administrative costs associated with deciding when an order is needed, selecting a vendor, and contracting for the order with the winning vendor. These are costs incurred by the ICP and not the manufacturing set-up costs experienced by a vendor. The latter costs are usually built into the unit cost of the item being manufactured. The vendor may decide to charge the same price for all units of an order or may elect to provide price breaks for larger orders. The costs addressed in this component also include the costs of issuing advertisements through synopsis in the Commerce Business Daily and time spent analyzing quotes and qualifying potential sources.

After contract award, there may be additional costs associated with issuing delivery orders for lots of that item ordered in the contract. Delivery orders are less expensive to issue, requiring just a short time to generate an order form. A delivery order is a document which schedules delivery of units under the shipping terms and conditions specified in the contract. Contracting vehicles already exist for this method of procurement because the government contracting community recognizes the advantage of flexibility in terms of quantity and delivery schedule.

The model accommodates other new trends in contracting. For example, quotations can be solicited requesting indefinite quantities within a minimum and maximum range. This leaves the government the option of purchasing any quantity within this range, rather than a specific amount, delivered in one lot. Delivery orders are then issued to space out deliveries throughout the year. The IDIQ (Indefinite Delivery, Indefinite Quantity) type contract is an example. The cost of contract award is then viewed as a constant which depends on the type of competition required, and the total dollar value of the award.

We assume in the model that, because of the low demand nature of RAMP candidates and short set-up times, contract awards (or work orders) can economically occur once annually, with delivery orders issued when the inventory position reaches the reorder point (RAMP interview, October 1993). This consideration of delivery order costs for subsequent deliveries once a contract has been negotiated deviates from the traditional total inventory management cost models such as the UICP consumable model.

A consequence of this order cost assumption is that for evaluation purposes, a constraint should be imposed restricting lot sizes to no more than one year's expected demand (IDIQ contracting, however, will allow more than that amount to actually be purchased if actual demand during the year is greater than expected). This constraint is important,

given that unexpected reductions in demand can rapidly create obsolescence. Reduction of the maximum procurement horizon from the current six quarters (in the UICP model) to four quarters as well as the use of the government's unilateral right to terminate a contract can ultimately help to reduce obsolescence.

The expected annual ordering costs are given by the following equation:

$$ORDERING\ COST = K + A\frac{4D}{Q},$$

where:

K = Annual cost of contract award;

D = Average quarterly demand forecast;

A = Cost of preparing a delivery order; and

Q = Lot size.

Note that if delivery orders are not allowed as part of a contract then A represents the cost of a new contract for each procurement (and K is set to zero in the model).

C. HOLDING COSTS

Holding costs are calculated by first determining the expected on-hand inventory in terms of unit-years held. Then that value is multiplied by the product of the holding cost rate ($/$-year) and the bid price from the vendor. The holding cost rate currently used by the Navy for consumable

items is 23 percent. This rate consists of three components; storage costs, obsolescence costs, and investment costs.

1. Storage Costs

The Department of Defense has determined that the cost of storing a consumable item for one year amounts for one percent of the value of the item per year. (DODINST 4140.39) This is extremely low when compared to industry, but the actual costs incurred are different between the government and private industry. It is less difficult for industry to quantify the overhead costs relating to holding inventory. Accounting costs relating to space, security, custodial, and other warehousing costs can be attributed to the specific inventory held within. With government storage, these costs are much less easy to determine. For example, when perimeter security is provided by the hosting Naval Station, the security cost of the warehouse is not of concern to the ICP. Similarly, most DoD inventory items are stored in warehouses built before and during World War II. These warehouses were fully capitalized long ago. Additionally, the government pays no insurance or property taxes.

2. Obsolescence Costs

Due to the large stockpiles of inventory in the wholesale system and rapid technology advances, obsolescence accounts for 12 percent of the 23 percent holding cost rate. (DODINST 4140.39) This is a major issue in today's austere fiscal

environment. As noted above, one key to reduction in this area is lowering the costs of awarding contracts (ordering costs), and encouraging industry to reduce set-up costs for production runs. The reason why lowering the ordering cost lowers the obsolescence rate is that as order costs are reduced, the optimal order quantity can be reduced as well. A short production lead time is another way of preventing or reducing obsolescence.

3. Investment Costs

This is the opportunity cost of the capital used to purchase the inventory items. OMB Circular A-94 of 29 October 1992 sets a real discount rate of seven percent as the opportunity cost which best approximates the marginal pre-tax rate of return on an average investment in the private sector. Most organizations, however, are reluctant deviate from the previous long standing opportunity cost rate of ten percent.

4. Formula for Holding Costs

The mathematical formula for the expected annual holding cost has the following form:

$$HOLDING\ COST = IC[E[OH]],$$

where:

I = Holding cost rate (currently .23);

C = Bid price of the item; and

E[OH] = Expected unit-years of on-hand inventory.

The calculation of E[OH] is based on the definition of inventory position (IP). Inventory position is defined as the number of units on-hand (OH) plus the number of units on-order (OO) minus the number of units backordered (BO). Thus, we can write the following formula for IP:

$$IP=OH+OO-BO.$$

This allows us to also write an equation for determining the expected value of inventory position, E[IP]:

$$E[IP]=E[OH]+E[OO]-E[BO].$$

Rearranging the terms gives us the equation for the expected on-hand inventory:

$$E[OH]=E[IP]-E[OO]+E[BO].$$

5. Expected Inventory Position

Inventory position can take on values in the range between the reorder point, R, plus one (R+1) and the reorder point plus the order quantity (R+Q). The ICP uses inventory position in its inventory management because inventory position acknowledges both the net inventory and the orders already outstanding for the item. Considering the stochastic nature of demand during procurement lead time, the use of a net inventory reorder point could result in an item never being reordered if it had a large demand which resulted in

such a large number of backorders that, even after an order arrived, the net inventory would remain below the reorder point.

The reason that the inventory range used in the model has a lower value of (R+1) is due to the fact than there is an infinitely small time that the inventory position spends at the reorder point R in the theoretical model (Hadley and Whitin, pg 181). (It should be noted that, in the real world, occasionally reorders are delayed due to fiscal constraints at the ICP and the actual inventory position may drop below R before an order is placed).

The probability that the inventory position assumes a particular value between R+1 and R+Q is uniformly distributed; that is, there is an equally likely chance that at any point in time the inventory position may lie at any of the Q possible values between R+1 and R+Q (see Hadley and Whitin, page 182).

The expected inventory position can be written as:

$$E[IP] = \sum_{x=R+1}^{R+Q} xp(x),$$

where p(x) is the probability that the inventory position is R+x. Since p(x)=1/Q for all x, this formula reduces to:

$$E[IP] = \frac{1}{Q}\sum_{x=1}^{Q} (R+x) \ .$$

Simplifying the summation gives the following results:

$$E[IP] = \frac{1}{Q}\left[\sum_{x=1}^{Q} R + \sum_{x=1}^{Q} x\right]$$

$$E[IP] = \frac{1}{Q}\left[QR + \frac{Q(Q+1)}{2}\right]$$

$$E[IP] = R + \frac{Q}{2} + \frac{1}{2} \ .$$

6. Expected on-order inventory

The expected value of on-order inventory is equal to the mean lead time demand, or μ (mu). Hadley and Whitin explain that this is intuitively obvious in the steady state demand environment to which this model applies. They state

> "Imagine orders flow into one end of a pipeline and that procurements flow out the other end. Since all demands are ultimately met, the mean rate of flow of demands ordered into the pipeline must be equal to the demand rate. Since an order remains in the pipeline for one lead time, the expected number in the pipeline should be the mean lead time demand, or μ."

That is,

$$E[OO] = \mu \ .$$

7. Expected backordered inventory

The expected number of backordered unit-years of inventory is a function of both the reorder point and the order quantity. We will use the following notation:

$$E[BO]=B(Q,R).$$

What remains is to provide a formula for determining the expected number of unit-years backordered, B(Q,R). The formula, under the assumption of Poisson demand, provided on page 184 of Hadley and Whitin, is:

$$B(Q,R)=\frac{1}{Q}\left[\sum_{u=R+1}^{\infty}(u-R-1)P(u;\mu)-\sum_{u=R+Q+1}^{\infty}(u-R-Q-1)P(u;\mu)\right],$$

where $P(u;\mu)$ = probability that lead time demand is equal to or greater than u, given the mean demand during lead time is μ. For ease of translation into LOTUS, the following transformation was used (see Hadley and Whitin, page 185):

$$\begin{aligned}\beta(v) &= \sum_{u=v+1}^{\infty}(u-v-1)P(u;\mu)\\ &=\frac{\mu^2}{2}P(v-1;\mu)-\mu vP(v;\mu)\\ &\quad+\frac{v(v+1)}{2}P(v+1;\mu).\end{aligned}$$

This results in the following formula for the expected unit-years backordered:

$$B(Q,R)=\frac{1}{Q}[\beta(R)-\beta(R+Q)].$$

8. Expected annual holding cost formula

The formula for annual holding costs is therefore

$$HOLDING\ COST = IC[E(IP) - E(OO) + E(BO)] = IC[R + \frac{Q}{2} + \frac{1}{2} - \mu + B(Q,R)].$$

D. TIME-WEIGHTED, ESSENTIALITY-WEIGHTED, REQUISITIONS BACKORDERED

This cost component is the penalty cost associated with the expected unit-years of requisitions backordered. Requisition-years are used because of DODINST 4140.39, whose objective is

> "To minimize the total of variable order and holding costs subject to a constraint on time-weighted, essentiality-weighted requisitions short."

Therefore, demands are assumed to occur in lots having some average requisition size in the calculation of requisitions backordered. As we will see in the next chapter, the cost per requisition-year backordered is driven by the "target risk" assigned to the particular item by the item inventory manager.

As for holding costs, where there are costs associated with maintaining an item in inventory, there are also costs of maintaining a item in a backordered status. In the case of backordered requisitions, however, the accounting cost of maintaining the requisition file and performing follow-ups represent just a fraction of the overall cost associated with that shortage. There is also a cost associated with the down

time of the end item. As we shall see later, the greater the criticality of the end item, the greater the backorder cost rate should be and the lower the appropriate target risk of stockout assigned by the Item Manager.

The backorder cost is an *implied* cost, which means that although it may be assigned a dollar value, it is never paid out in cash. The UICP formula for the expected annual time-weighted, essentiality-weighted requisitions backordered cost is:

$$BACKORDER\ COST = \frac{\lambda E}{S} B(Q,R),$$

where:

λ = The shortage cost per requisition-year backordered;

E = An essentiality factor between 0 and 1;

S = The average customer requisition size, 1 in most cases involving RAMP items; and

B(Q,R) = The expected unit-years of inventory backordered.

The units of the shortage cost λ are dollars per requisition-year short. The average annual unit-years of requisitions backordered is approximated by dividing the unit-years of backordered inventory, B(Q,R), by the average number of units in the customer's requisition, S. Finally, the insertion of the essentiality factor is provided for weighing the relative importance to fleet readiness of this particular item against others in the same general category of material.

However, for the purposes of evaluating vendor proposals for a given item, the essentiality factor will be the same for each vendor's proposal, The default value of E is therefore 1.0 in the model.

E. EXPECTED ANNUAL PROCUREMENT COSTS

Finally, we must consider the total expected annual hardware procurement costs at the price proposed by each bidder. Those costs are simply the product of four times the quarterly demand and the unit price (C); that is, 4DC.

F. EXPECTED TOTAL ANNUAL COST EQUATION

Combining all the cost components yields the following equation for the expected total annual costs:

$$TAC=K+A\frac{4D}{Q}+IC[R+\frac{Q}{2}+\frac{1}{2}-\mu+B(Q,R)]+\frac{\lambda E}{S}B(Q,R)+4DC.$$

III. SHORTAGE COSTS AND TARGET RISK

A. DERIVATION OF LAMBDA

We are ready to discuss the calculation of the shortage costs driven by the target risk. In this chapter, we derive the risk formula and the shortage cost known as lambda (λ) and then discuss the use of the formula by the item inventory manager.

Target risk defined here is that risk of stockout which provides maximum utility to the government. As noted in Chapter I, an inventory manager typically knows the desired service level for a particular item. This service level is the probability of filling all requisitions between the time a stock replenishment order is placed and the order is received into the supply system. Based on this service level, a target risk of not filling all requisitions can be determined using the formula:

$$\text{Target Risk}=1-\text{Service Level.}$$

The concept of target risk assumes that any greater risk of stockout would be expected to result in higher expected annual backorder costs when the implied cost of a stockout associated with the target risk is used in the expected costs equation. A lesser risk of stockout would not provide greater utility to

the government either as the expected annual holding costs for maintaining inventory levels would be higher.

To understand how the target risk is used to generate the implied shortage cost we need to first determine the optimal reorder point assuming that lambda is known. For convenience, we restate the formula for expected total annual costs developed in the last chapter and call it TAC(R) to emphasize that we are going to focus on the fact that it is a function of R:

$$TAC(R)=K+A\frac{4D}{Q}+IC[R+\frac{Q}{2}+\frac{1}{2}-\mu+B(Q,R)]+\frac{\lambda EB(Q,R)}{S}+4DC.$$

The following figure illustrates the expected total annual costs as a function of the reorder point. The value of R shown results in lowest expected total annual costs. To determine this value we must determine the largest value of R in which $\Delta TAC=TAC(R)-TAC(R-1)\leq 0$.

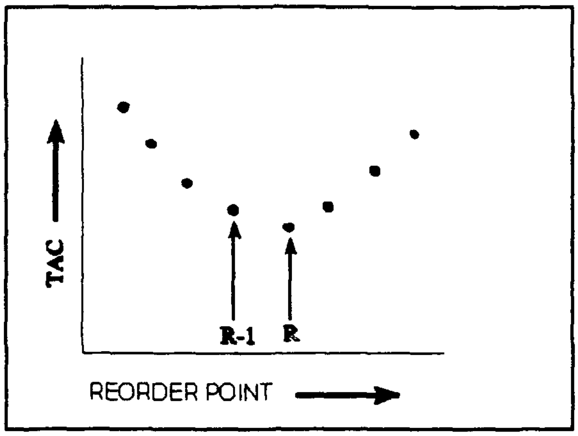

Figure 1. Expected total annual costs with respect to the reorder point.

We begin by writing the equations for TAC(R) and TAC(R-1) in an expanded form:

$$TAC(R) = K + A\frac{4D}{Q} + ICR + \frac{ICQ}{2} + \frac{IC}{2} - \mu IC + ICB(Q,R) + \frac{\lambda EB(Q,R)}{S} + 4DC;$$

$$TAC(R-1) = K + A\frac{4D}{Q} + IC(R-1) + \frac{ICQ}{2} - \mu IC + ICB(Q,R-1) + \frac{\lambda EB(Q,R-1)}{S} + 4DC.$$

Next, subtracting TAC(R-1) from TAC(R) yields

$$\Delta TAC = [ICR + ICB(Q,R) + \frac{\lambda E}{S}B(Q,R)] - [ICR - IC + ICB(Q,R-1) + \frac{\lambda E}{S}B(Q,R-1)].$$

Collecting terms and simplifying reduces the finite difference to

$$\Delta TAC = IC + [IC + \frac{\lambda E}{S}][B(Q,R) - B(Q,R-1)].$$

Optimization requires this difference to be equal to or less than zero. By rearranging terms and multiplying both sides of the inequality by S, the resulting inequality is

$$[SIC + \lambda E][B(Q,R) - B(Q,R-1)] \leq -SIC.$$

Finally, by dividing both sides of the inequality by [SIC+λE} yields

$$B(Q,R) - B(Q,R-1) \leq -\frac{SIC}{SIC + \lambda E}.$$

We can rewrite the formula for B(Q,R) in the following form (Hadley and Whitin, p.184):

$$B(Q,R) = \frac{1}{Q}\sum_{y=0}^{\infty} y[P(y+R+1;\mu) - P(y+R+Q+1;\mu)].$$

Then, by substituting (x-R) for y, we get

$$B(Q,R) = \frac{1}{Q}\sum_{x=R}^{\infty} (x-R)[P(x+1;\mu) - P(x+Q+1;\mu)].$$

Similarly, for B(Q,R-1), we get

$$B(Q,R-1)=\frac{1}{Q}\sum_{x=R-1}^{\infty}(x-(R-1))\,[P(x+1;\mu)-P(x+Q+1;\mu)]\,.$$

The difference of the two is

$$B(Q,R)-B(Q,R-1)=\frac{1}{Q}\sum_{R}^{\infty}(-1)\,[P(x+1;\mu)-P(x+Q+1;\mu)]\,.$$

We now can replace B(Q,R)-B(Q,R-1) in the inequality by the right-hand side of this equation. We then multiply each side by -Q to get

$$\sum_{x=R}^{\infty}[P(x+1;\mu)-P(x+Q+1;\mu)]\geq\frac{SQIC}{SIC+\lambda E}.$$

It is difficult to easily find R from this inequality. Therefore, we need to develop an approximation to the left-hand side of this inequality. The approximation we will argue was developed by the Fleet Material Support Office in the early 1970's. For the sake of clarity, it is best to argue the derivation of the approximation graphically. Figure 2 shows a typical form of $P(x;\mu)$. Our focus is on the discrete case, but for ease of illustration, we assume the P(x) curve approximates that of a continuous probability distribution.

Doing so will allow the consideration of certain "areas" under the P(x) curve.

First, we separate the left-hand side of the inequality into its two components as follows:

$$\sum_{x=R}^{\infty} [P(x+1;\mu)-P(x+Q+1;\mu)]$$
$$=\sum_{x=R}^{\infty} P(x+1;\mu)-\sum_{x=R}^{\infty} P(x+Q+1;\mu),$$

and replace the infinite upper bound by a value (m-1) where m is larger than R+Q. This gives us the following formula:

$$\sum_{x=R}^{m-1} P(x+1;\mu)-\sum_{x=R}^{m-1} P(x+Q+1;\mu).$$

Next, we divide the area under the P(x) curve into the different "areas" shown in Figure 2 and relate those areas to the formula above. In Figure 2, because x can only take on integer values, area 1 has a base which goes from R+1 to R+Q, area 2 has a base which goes from R+Q+1 to m, and area 3 has a base which goes from m+1 to m+Q.

We can see that the first term of the formula corresponds to the sum of area 1 and area 2. Therefore we can write

$$\sum_{x=R}^{m-1} P(x+1;\mu)=\text{area 1}+\text{area 2}.$$

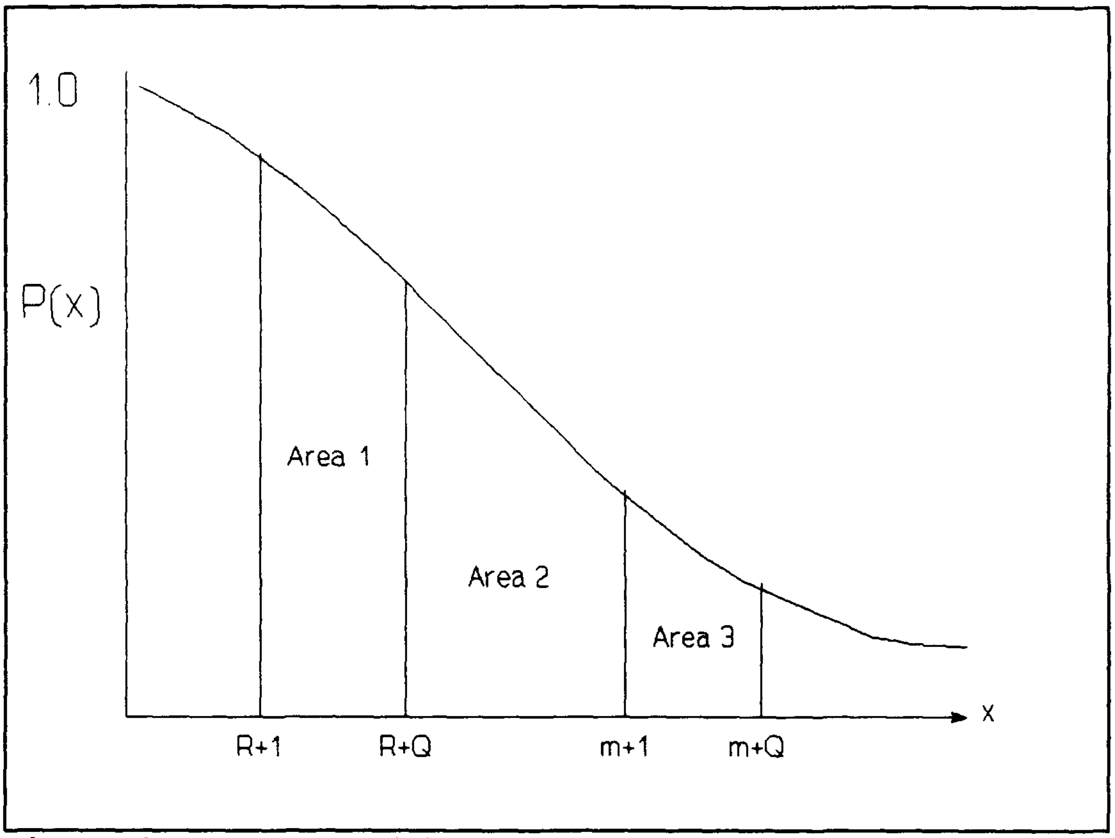

Figure 2. Areas of P(x) used to argue the approximation.

Similarly, we see from Figure 2 and our definition of the base of area 2 that the second term of the formula is represented by the sum of area 2 and area 3. Therefore, we can write:

$$\sum_{x=R}^{m-1} P(x+Q+1;\mu) = \text{area 2} + \text{area 3}.$$

The difference between the first and second terms of the formula is then

(area 1 + area 2) - (area 2 + area 3) = area 1 - area 3.

From our definition of the bases of areas 1 and 3, we know that

$$\text{area } 3 = \sum_{x=m+1}^{m+Q} P(x;\mu)$$

$$\text{area } 1 = \sum_{x=R+1}^{R+Q} P(x;\mu)\,.$$

When we take the limit of the area 3 formula as m goes to infinity we realize that $P(x) \to 0$ and area 3 approaches zero; i.e.,

$$\lim_{m\to\infty} \sum_{x=m+1}^{m+Q+1} P(x) = 0\,.$$

What remains to be done now is to examine area 1. As the first step, we subdivide area 1 as shown in Figure 3.

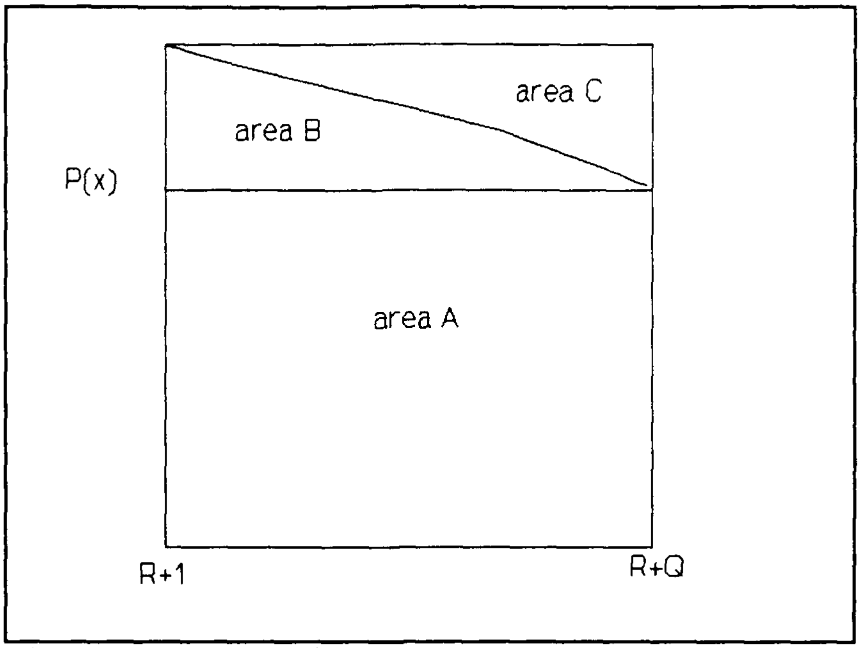

Figure 3. Subdivisions of area 1.

In figure 3 we have selected areas A and B such that area 1 is equal to their sum. Rather than attempting to remain with the formula given above for area 1, we focus instead on deriving bounds for the value of that area. The upper bound is the sum of areas A, B, and C and the lower bound is area A. Thus we can write

$$area\ A \leq area\ 1 \leq area\ A + area\ B + area\ C$$

Next, we realize that

$$area\ A = QP(R+Q;\mu),$$

since the "length" of the base of the area is Q (since the base goes from R+1 to R+Q) and the height is $P(R+Q+1;\mu)$. Similarly,

$$area\ A + area\ B + area\ C = QP(R+1;\mu).$$

Substituting these results into the area 1 inequality above gives

$$QP(R+Q+1;\mu) \leq \text{area } 1 \leq QP(R+1;\mu).$$

Now, if we assume that

$$area\ 1 = \sum_{x=R}^{\infty} [P(x+1;\mu) - P(x+Q+1;\mu)] \approx \frac{SQIC}{SIC+\lambda E},$$

then we can replace area 1 by the right-hand side of this approximation. The result is

$$QP(R+Q+1;\mu) \leq \frac{SQIC}{SIC+\lambda E} \leq QP(R+1;\mu).$$

Dividing each term by Q yields:

$$P(R+Q+1;\mu) \leq \frac{SIC}{SIC+\lambda E} \leq P(R+1;\mu).$$

Finally, we are interested in determining the largest value of R which satisfies the inequality. That corresponds to the case where

$$P(R+1;\mu) \geq \frac{SIC}{SIC+\lambda E}.$$

By definition, $P(R+1;\mu)$ is equal to the probability of stockout just before the next order arrives. We have also shown via the finite difference argument that the right-hand side of the inequality is the "risk" of stockout which minimizes the expected total annual inventory management costs.

This risk inequality is used by the ICPs for determining the optimum reorder point for inventory position. In doing so, all the parameters on the right-hand side, including λ, are systems constants.

If the calculated value of the right hand side exceeds acceptable risk values, the risk is constrained to a minimum or maximum value determined by the ICP for each cognizance symbol. If this occurs, it can be argued that the optimality of the equation is diminished; that is, the total expected annual costs will not be as low as they would be without the constraint, assuming λ has a valid value. On the other hand, since the ICP's have determined values for the constraints, it implies that the shortage cost parameter λ selected by the ICP's does not always provide the desired reorder point.

Appendix B shows the different ranges of allowable risk values and λ values for SPCC managed items (all items are grouped into four-digit cognizance classes).

In the model we determine the reorder point first using the following formula:

$$P(R+1;\mu) \geq TARGET\ RISK.$$

The reorder point is the largest value for which this inequality holds. We do not need to constrain target risk since we assume the inventory manager knows what is feasible and reasonable in selecting its value.

Next, we set the right-hand side of the inequality equal to a value which we will call "target risk" as the first step towards determining the value of λ.

$$\frac{SIC}{SIC+\lambda E} = TARGET\ RISK.$$

The target risk equation can then be rewritten to solve for the corresponding value of λ.

$$\lambda = \frac{SIC}{E}\left(\frac{1}{RISK}-1\right),$$

where "RISK" is the shorthand notation for the value of TARGET RISK.

Note that the units of this shortage cost are dollars per requisition-year. Once it is determined, it can be used in the expected total annual costs equation to determine the expected annual requisition shortage costs. The result is a much more realistic value for an item's penalty cost for backorders than can be expected from the UICP model.

B. APPLICATION TO THE MODEL

The model first calculates the reorder point and λ as described above and then the optimal lot size, Q^*, by determining the expected total annual inventory management costs for each value of lot size and searching for that Q which minimizes the expected total annual costs. This first requires determining the expected number of delivery orders per year, the expected unit-years on-hand and expected unit-years backordered for each Q value.

1. The model calculates the ordering costs in accordance with the ordering costs formula from Chapter II, using parameter values and the given value of Q. Recall that the equation is

$$ORDERING\ COSTS = K + A\frac{4D}{Q}.$$

2. The statistical calculation module is used to perform the computations to determine the expected unit-years on-hand and backordered for a given Q and R value. It first

calculates the unit years backordered using the B(Q,R) formula presented earlier in this chapter:

$$B(Q,R)=E[BO]=\frac{1}{Q}[\beta(R)-\beta(R+Q)];$$

where

$$\beta(v)=\frac{\mu^2}{2}P(v-1;\mu)-\mu vP(v;\mu)+\frac{v(v+1)}{2}P(v+1;\mu).$$

In this formula μ is the expected lead time demand (the product of forecasted average quarterly demand and procurement lead time based on the vendor's production lead time. To compute β(Q,R) we need to replace v by R and R+Q in the β(v) formula.

The next step is to calculate the unit-years of on-hand inventory as follows:

$$E[OH]=R+\frac{Q}{2}+\frac{1}{2}-\mu+B(Q,R).$$

The value of Q is vital to the determination of the expected on-hand value. In the calculation of the Q/2 term, the smaller the value of Q, the lower its value. However, in the B(Q,R) formula, Q appears in both the numerator and denominator. In the numerator, decreasing Q increases the value of β(R+Q), reducing the expected number of backorders but, because [β(R)-β(R+Q)] is then divided by Q, the smaller

the value of Q, the greater the expected unit-years backordered may be.

3. The expected annual holding costs for inventory on hand is computed as the product of the holding cost rate, the proposed unit price, and the expected unit-years of on hand inventory. As discussed in Chapter II, the formula is

$$ICE[OH] .$$

4. The expected annual backorder cost is a function of the target risk as well as Q. The shortage cost λ is the cost per requisition-year and is computed using the formula derived in the preceding section; that is,

$$\lambda=\frac{SIC}{E}\left(\frac{1}{RISK}-1\right) .$$

Dividing λ by SC (the average cost of a requisition) gives a shortage cost rate

$$\lambda'=\frac{\lambda E}{SC},$$

that can be compared to the holding cost rate I. In fact, when the target risk is .50 and the essentiality factor E assumes the default value of 1.0, we get λ'=I.

The cost of the expected unit-years of requisitions backordered is then calculated using the following formula:

$$\lambda' CB(Q,R)\,.$$

5. The expected costs of ordering, holding, and having backorders (all functions of Q) are added to the contract award and average annual procurement costs to achieve the expected total annual costs for a given Q value.

Once the optimal value of Q is determined (the Q value which minimizes the expected total annual costs), each cost component of the total annual costs is displayed in the model's analysis section, along with other relevant data to compare the best value each vendor has to offer.

Analysis of the proposals using the vendor evaluation model will also yield the proper time to order; either immediately or at a later time when the inventory position has been reduced to the new reorder point. This is a decision based on the value of the procurement lead time associated with the bid.

1. Payback Period

A permanent reduction in the reorder point allows for recovery of funds through the reduction of required inventory levels. This recovery can be used to fund the reverse engineering effort required to convert existing drawings to NC machine-compatible form. It is possible to calculate the amount of time required to achieve this recovery. The payback

period for the reverse engineering function for each item can be determined by the following equation:

$$t=\frac{R-R'}{D},$$

where

R = the original reorder level;

R'= the revised reorder level;

D = the demand rate; and

t = the payback period in quarters.

The expected dollar value of this recovery can also be calculated by applying the unit cost to the difference in reorder point, as follows:

$$RECOVERY = (R-R')\,C.$$

IV. THE BEST VALUE MODEL

A. APPLICATION

The Best Value model can be used to evaluate vendor proposals, determining which bidder offers the price and lead time most advantageous to the government. It incorporates the four cost components defined by DODINST 4140.39 and provides a method to optimize the expected total annual inventory management costs with respect to the reorder point and the lot size.

There is another use for this model. It provides a very simple and rapid means to determine the reorder point for an item in which the procurement price, lead time, or lot size have changed. This model is very flexible in that it can be used to determine the existing protection level afforded an item, and can be used to determine affordable lot sizes, reorder points, etc., when budgetary constraints are imposed.

In this chapter, we first describe the types of items appropriate for evaluation by the model. We then compare the model with two other total annual cost models, namely the UICP consumable model and Q Star. Following that, we describe the on-screen format of the model, including the data entry fields and analysis sections. Finally, we discuss the procedures for

conducting an evaluation and interpreting the results generated by the model.

B. ASSUMPTIONS

This model is designed for a specific type of cost evaluation. The associated assumptions are listed below:

1. Steady state requirements: The average quarterly demand must be expected to be relatively steady over the next four quarters. Forecasting is never precise, and the model can accommodate minor variations in the average quarterly demand without serious impact on the reliability of the results. However, if the item is certain to experience a sharp increase or decrease in average quarterly demand over the next four quarters, this model is not appropriate.

2. The item must have moderately low lead time demand: Because of the probability distribution used in this model, the lead time demand should be less than 50 units. There is a dialogue box that warns the user if this maximum is exceeded. The lead time demand is calculated by multiplying the average quarterly demand by the total procurement lead time (in quarters).

3. The item's quarterly demand should follow a Poisson distribution: The Poisson distribution was used in this model because it is generally accepted as that which best simulates the actual variability for items of low to moderate demand. It is acknowledged that the user of the model will most often

be unable to recognize the probability distribution. As a general guideline, the user should consider the following situations:

a. If the average quarterly demand is <u>extremely low</u>, (i.e., less than .25 per quarter, or 1 per year), the probable future demand of item should be investigated in further detail. The model can be applied if the result of the investigation yields a candidate in which the average future quarterly demand is relatively constant even though some variability occurs. That variability should satisfy assumption d. below.

b. If planned requirements account for the majority of the next four quarter's demands, the Poisson probability distribution may not be appropriate. In such a case, there is little or no chance of stockouts because the expected lead time demand can be estimated with greater accuracy than is assumed by this model.

c. Although the parameters section allows for entries of average customer requisition sizes, the Poisson distribution is based on the premise that demands for items occur individually (i.e., a requisition quantity of one unit). Items which are expected to be regularly issued in average quantities between .85 and 1.15 units are appropriate for this model.

d. The Poisson probability assumes a demand variance equivalent to the mean. If the quarterly demand data

demonstrates a significantly greater or lesser variance than the mean quarterly demand, the model should not be used.

C. THE MODEL

The model is designed to be run in LOTUS 123 Version 2.2 or higher. The WYSIWYG add-in is also required to ensure the proper formatting of the output.

This model performs calculations in two major steps. The first is to calculate the optimal reorder point and order quantity for the vendor's proposed unit cost and production lead time. The second is to calculate the expected on-hand inventory and the expected number of backorders, given the optimal reorder point and order quantity. Both these expected values are calculated in unit-years. Finally, cost factors are assigned to the expected unit-years held and backordered. Both of these are added to the contract award and delivery order costs and the average annual hardware procurement costs. The result is the value for the expected total annual costs.

The model consists of an input module, a comment section, and four statistical analysis modules. The input module provides the fields for entering item parameters, nomenclature, and vendor bid information. The comment section contains advisories regarding possible input errors and other prompts. The first three statistical analysis modules provide the computations of expected values based on price break quantities and unit costs. The fourth module calculates the

expected values and cost components based on the maximum lot quantity of one year's worth of demand. The purpose of this is to ensure that the constraint on requisition lot size is enforced. In addition to expected values and cost breakdowns, the first analysis module has been formatted to provide other useful information which is ultimately printed on the bid evaluation worksheet (Appendix A).

1. Similarities and Differences with the UICP Consumables model

The Best Value Model is very similar to the UICP model, calculating the total average annual variable costs in terms of procurement, holding, backordering, and ordering costs. The costs are different in the following ways:

1. The UICP model uses historical data to estimate procurement lead time and unit cost in calculating the optimal reorder point and lot size. The Best Value Model considers the bid production lead times and proposed unit prices in determining the future expected total annual inventory management costs of a continuing series of purchases from a certain vendor.

2. The UICP consumables model provides an implied shortage cost per requisition-year backordered which will provide an overall availability for that family of items. It is not sensitive to unit cost or required service level (urgency of need). This shortage cost may create an "optimum" risk value

which falls outside the risk constraints developed by the ICPs in their attempt to meet other goals.

The Best Value Model calculates the implied shortage cost per requisition-year backordered, using "target risk" as a parameter and has no risk constraints. The expectation is that this target risk will consider all of the UICP goals. The expected total annual costs for the associated reorder point and order quantity are computed using this value and are then used in the bid evaluation process.

3. The UICP consumables model is not capable of evaluating bids involving quantity discounts. The Best Value Model can calculate the reorder point and economic lot size for fixed price/lead time bids as well as quantity discount bids with fixed or varied lead times.

2. Similarities and Differences with Q Star

Q Star was a program developed by SPCC for the purposes of determining the optimum lot size and procurement lead time combination. It failed implementation because it apparently created an unacceptable amount of additional administrative workload for the contracting activity. It required the identification of potential vendors, evaluating their preliminary bids by running the program, and asking for best-and-final offers (SPCC interview October 1993). It did provide a quantity discount option and came with many sophisticated functions which provided tremendous insight into

the overall impact of procurement lead time, unit cost, and maintenance of inventory items. The Best Value Model is quite similar to Q Star (Project Q Star, 1985) with regard to the expected total annual costs calculation.

D. INPUT SECTION

There are three portions to this section. They are the parameters section, nomenclature, and vendor bid data.

1. Parameters section

This is data obtained from the Master Data File (MDF) and provided to the ICP user via the bid evaluation worksheet data entry sheet (Appendix C). The data entered into this section is detailed below and appears on the computer screen as shown in Figure 4.

Parameters:

5	Quarterly Demand
42	Current Reorder Level
20	Current Inventory Position
1	Essentiality
1	Avg. Units/Requsition
$750	Award Cost
$75	Delivery Order Cost
0.23	Holding Cost Rate
0.1	Target Risk

Figure 4. The parameters section, used for entering ICP data.

a. <u>Quarterly demand</u>: This is the forecasted average quarterly demand for the item.

b. <u>Current reorder level</u>: This is the inventory position's current reorder point value.

c. <u>Current inventory position</u>: This is the inventory position at the time of referral. It should be the inventory position at the start of the procurement lead time.

d. Essentiality: This is a mission essentiality factor which must be between 0 and 1. The default value for this parameter is one, and procurement personnel should only use one unless specified otherwise by the item manager. This factor weights the backorder cost, and values other than one may be used by the item inventory manager to compare competing items within his cognizance.

e. Average units per requisition: This is the forecasted average quantity of units in each customer requisition. Recall that the average requisition size should be very close to a value of 1.0 for the Poisson probability distribution to be valid.

f. Award Cost: This is the annual fixed cost of awarding the contract to the vendor and renewing it each year. Each procurement activity, including the ICPs, should have an estimate of the award cost, which is based on the type of competition conducted. If the value is identical for each vendor, the award cost does not affect the decision, and could, in fact, be ignored, or set to zero.

g. Delivery Order Cost: This is the administrative cost of preparing and issuing the delivery order or work request, and processing the receipt of the lot. It excludes the item hardware procurement costs, which are entered in the vendor bid data fields. In an effort to reduce excessive inventory levels, this cost should be accurately calculated, and procurement personnel should continue striving to reduce this

cost. (Vendors should strive to reduce their set-up costs for production runs as well.) Reduction of both of these costs will help to reduce inventory levels.

h. Holding Cost Rate: The holding cost rate is the estimate of the cost of holding one dollar of inventory for one year. This cost is also very important to accurately assess. The higher the holding cost rate, the higher the expected costs of maintaining inventories. As mentioned earlier, the ICP value of .23 is low when compared to industry (Schonberger, 1991). The recognition of higher costs of maintaining inventories lends itself to Just-In-Time inventory practices. Vendors who allow the customer to maintain lower inventory levels through rapid delivery of materials are then preferred.

The largest component of the holding cost rate is the obsolescence of the inventory item prior to delivery to the end user. Reducing the production lead time can help to reduce the obsolescence component in the long run. Reducing production lead time allows the reorder point to be reduced. This means reducing the inventory level required to satisfy mean lead time demand and the safety stock required to accommodate the variability of demand.

i. Target Risk: This is the risk of stockout which should provide the best value to the government. It should be supplied by the Item Manager after careful consideration of the costs and benefits of maintaining the appropriate service level for a particular item. The model can also determine the

service level currently being afforded to the item. This is accomplished by examining relationship between the average quarterly demand and the current reorder level. As mentioned earlier, consideration of risk should include not only the accounting costs of maintaining a backordered requisition for one year, but also the ramifications of the operational loss of capability of the end item being supported. This value should not be difficult to determine. Currently, all ICP managed items are bracketed by a range of acceptable stockout risks. Appendix B lists examples of SPCC's values for consumable items. Recall from Chapter III that by using the systems constants which include lambda, the ICPs first compute the optimal risk using the formula

$$RISK=\frac{SIC}{SIC+\lambda E}.$$

Then they check to see if its value falls within their allowable range of risk values. Usually this range is narrow, (i.e., .10 to .35), so assuming that this range is appropriate for the item, all that remains to be done is to choose a specific value within that range as the target risk. If the target risk cannot be easily determined, the user may choose to default to the minimum risk value. This assures adequate protection for the item by defaulting to the most costly, in the sense of carrying inventory, risk of stockout acceptable to the ICP. If storage cost constraints exist, target risk

can be increased up to the maximum allowable value for the item's four-digit cognizance code. This will decrease the reorder point and hence the inventory holding costs but at the expense of decreased protection.

j. Nomenclature: This box (see Figure 5) is provided to identify the item and the vendor to aid in comparison of the completed worksheets in the procurement documentation file. Entering the item name, National Item Identification Number (NIIN) and vendor helps to ensure that worksheets are properly identified. (Note that the NIIN must be entered as text, or LOTUS 123 will recognize it as a formula.)

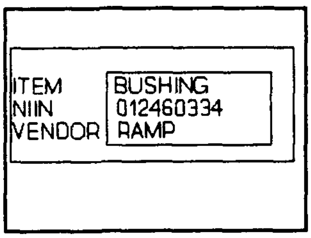

Figure 5. The Nomenclature box.

2. Vendor Bid Input

The entries in this section are specific to each particular vendor's bid. The information required of competing vendors are their price ranges and associated production lead times.

1. Procurement Lead Time: There are two entries that are needed to determine procurement lead time. The bid production lead time field is used to enter the time in days from contract award to delivery of the first item. The administrative lead time field is provided to assist the Item Manager

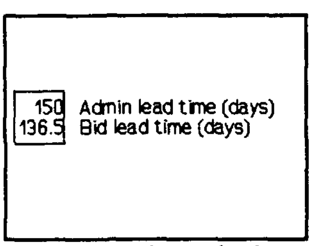

Figure 6. Fields for ICP admin lead time and vendor production lead time.

or procurement specialist in determining the inventory position reorder point. When an item's inventory position reaches the reorder point it marks the time at which administrative procurement actions should begin. The sum of these two fields is the total procurement lead time. For convenience, the units entered for both of these fields are days. They are converted to quarters in the analysis section.

2. Bid Price/Quantity Section: Vendor pricing data from the bid evaluation worksheet data input sheet is entered in this portion of the input section. If the quoted price is the same for the entire range of the bid, quantities roughly evenly spaced between the minimum and maximum lot quantities should be entered in the quantity sections, and the same price entered in all four price fields. If there are price breaks for larger lot sizes, the minimum quantity for each price should be entered in the quantity section, with its corresponding price in the price field to the right. The bottom quantity field automatically enters the maximum allowable lot size (one year's expected demand). The user must ensure that the

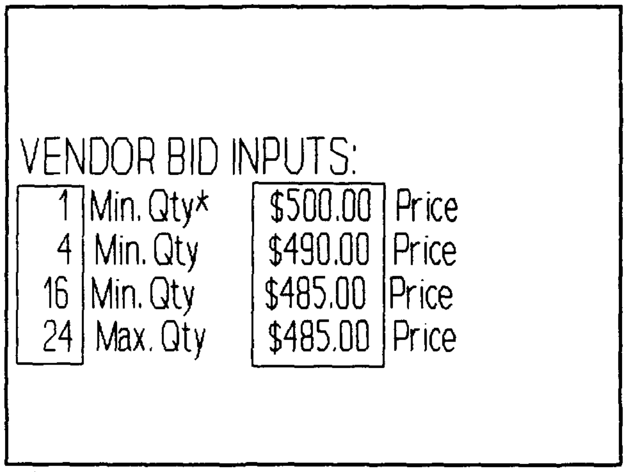

Figure 7. Vendor lot size and pricing fields.

correct price is entered in the Maximum quantity field. The value appearing in any Min. Qty. quantity field should not exceed that which appears in the bottom quantity field labeled Max. Qty.

Comments:

Warning! This model loses accuracy when lead time demand exceeds 50
CAUTION! Possible error! Ensure lot size cannot exceed max annual buy
CAUTION! Possible error! Lowest cost lot must be entered in Min Qty* block
WARNING! This reorder point exceeds target risk. Risk of stockout: 47.00%

Figure 8. The comment dialogue box.

E. COMMENT SECTION

This section, which can be observed on the screen as the evaluation process is performed, warns of possible errors, and aids the user in preparing the bid evaluation worksheet (the output of the model). Any combination of the above comments appearing in Figure 8 may appear during the evaluation process.

1. The first warning indicates that the lead time demand is beyond the allowable fifty units. If this warning appears, this model should not be used for vendor evaluations.

2. The second message indicates that the quantity entered in one of the Min. Qty. fields exceeds one year's expected demand.

3. The third message will prompt the user to enter the optimal lot size in the Min Qty* position on the top line of Figure 7 after it has been determined. The purpose of entering the optimal lot size and corresponding price in this field is to provide information for the Bid Evaluation Worksheet. When the worksheet is printed it will reflect the best value the proposal has to offer.

4. The final warning will appear if the current reorder point will cause the target risk to be exceeded. This will occur if the next order is to be obtained from a vendor whose production lead time is longer than the value currently in the ICP's Master Data File for this item. This prompts the user to adjust the reorder point prior to issuing the next delivery order.

F. ANALYSIS SECTION

This section provides a detailed breakdown of the expected annual costs associated with the purchase option which results in the lowest expected total annual cost to the government. In the left-hand center section of Figure 9 it also displays

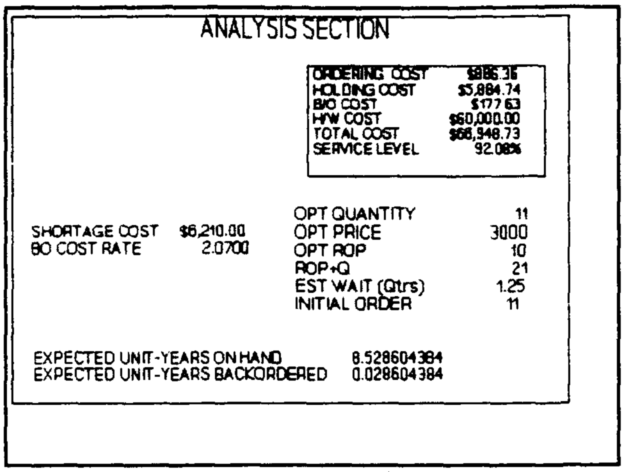

Figure 9. The analysis section of the bid evaluation worksheet.

the expected shortage cost in dollars (λ) per requisition-year and the backorder cost rate (λ') which has the same units as the holding cost rate. The expected unit-years on hand and the expected unit-years backordered shown at the bottom of Figure 9 are calculated as a function of the reorder point and the lot size using the Poisson probability distribution contained in the statistical calculation section. A portion of the statistical calculation section appears below in Figure 10 and shows the calculated probabilities associated with various values of the reorder point when the mean lead time demand (μ) is 5.21978. This section also generates the two values of β for optimal R and Q which are needed for calculating the expected unit-years on-hand and backordered which appear in the analysis section.

In the right-hand center of the analysis section is a summary of important procurement data such as the optimal lot size, unit price, reorder point, maximum inventory position afforded by this particular vendor (ROP+Q), the expected wait time before the next order should be placed with the new vendor, and the initial order size.

The cost calculations performed by the model are shown in the upper right-hand corner of Figure 9. They were discussed in detail in an earlier chapter; They will be only briefly reviewed here.

BETA R	0.273474659
BETA R+Q	0.000017643
MU	5.219760219

R	p(R)	P(LTD<=R)	P(LTD>=R)
0	0.005408517	0.005408517	1
1	0.028231273	0.033639791	0.994591482
2	0.073680521	0.107320313	0.966360208
3	0.128198710	0.235519023	0.892679686
4	0.167292262	0.402811295	0.764480976
5	0.174645779	0.577457075	0.597188704
6	0.151935430	0.729392505	0.422542924
7	0.113295650	0.842688156	0.270607494
8	0.073922299	0.959483584	0.157311843
9	0.042873128	0.959483584	0.083389543
10	0.022378830	0.981862415	0.040516415

Figure 10. The statistical calculation section.

a. <u>Ordering cost</u>: This is the expected annual costs of contract award plus the cost of issuing the expected required number of delivery orders.

b. <u>Holding cost</u>: This is the expected annual holding costs and is the product of the holding rate, the bid price at this lot size (and reorder point), and the expected units-years of on-hand inventory (shown at the bottom of Figure 9).

c. <u>Backorder (B/O) cost</u>: This is the expected annual costs of requisitions short and is the product of the shortage cost rate λ', the unit cost at this lot size, and the expected unit-years of demand backordered.

d. <u>Annual Procurement costs (Hardware Costs)</u>: This is the expected annual costs of procuring the item and is the product of the average annual demand quantity and the optimal unit price associated with the optimal lot size.

G. VENDOR BID EVALUATION PROCEDURE

1. Bid Evaluation Worksheet Data Input Sheet

The first step in evaluating vendor proposals is for the item inventory manager to complete the top portion of the Bid Evaluation Worksheet Data Input Sheet shown in Appendix C. The parameter data can be retrieved from the Master Data File (MDF). In addition to MDF data, the item manager must also supply other information to the procuring agency such as target risk and current holding cost rate. If target risk can not be specified, the item manager should use a typical minimum risk such as those shown in Appendix B. Estimated contract award costs are entered commensurate with the ICP established value appropriate for this type of competition. Finally, an estimated delivery order preparation cost must be entered. Because this is a new parameter, an estimate of this dollar value should be based on the average labor-hours required to prepare and issue delivery orders.

The procuring agency then completes the vendor bid data portions of the data sheet, including a section for each qualified prospective vendor. Once the data input sheet has been completed, the contractor personnel are ready to enter the data into the model.

2. Parameter and Nomenclature Data Input

Once the model has been retrieved onto the computer screen, the user will be able to see all the sections of the

spreadsheet which require entries (parameters, lead time, nomenclature, vendor bid input) plus the comment section. The operator enters the parameter data and vendor input information for the first vendor in the appropriate fields describe earlier in this chapter. In addition, the user must ensure that the item meets the demand criteria suitable for this model; specifically, that the demand information is consistent with that in Section B of this chapter. The item description, NIIN (in text format), and the vendor being evaluated first are entered in the nomenclature section. Then the user enters the quarterly demand rate, current reorder point, current inventory position, essentiality (optional), estimated award cost, holding cost rate, and target risk. Section D of this chapter provided descriptions and sources of the parameter data.

3. Vendor Bid Data Input

a. Administrative and Procurement Lead Time Input

Since the evaluation is based on total procurement lead time, the user needs to enter the estimated administrative lead time for the type of procurement. Then, the production lead time should be entered. If the vendor offers different production lead times for each pricing scheme, each lead time scenario must be evaluated separately.

b. Single price range

If only one price is proposed for the entire production range, the user should enter that quoted price in all four price fields and insert the vendor's minimum lot quantity for this price in the uppermost (Min. Qty*) field. Two other eligible lot sizes evenly spaced between the vendor's minimum lot size and the default maximum lot size appearing in the bottom quantity field (Max Qty) should be entered in the remaining quantity (Min. Qty.) fields. This will facilitate the model's performing of the iterative procedure required to determine the optimal lot size. For example, if the minimum lot size for the bid price is 5 and the maximum quantity is 20, 10 and 15 are good candidates for entry in the remaining two fields.

c. Price breaks for different lot sizes

Insert the smallest qualifying lot size for each unit price in the three quantity fields and their corresponding unit prices to the right. The bottom quantity field automatically defaults to four quarters of demand so it requires no entry by the user. However, the user does need to determine in which price range this maximum lot size belongs and enter the associated unit price in the corresponding price field. Lot sizes exceeding the default value will be excluded from evaluation.

4. Determining the optimal reorder point

Now that the parameters, nomenclature, lead time, and vendor bid data has been entered, the user is ready to determine the optimal reorder level and then the optimal lot size. If the user is evaluating a sole source proposal, the model can be used to minimize the inventory management costs associated with this single vendor. If comparing multiple vendor proposals, each proposal must be optimized as in the sole source scenario, and then compared against the others to determine which vendor can provide the best value in terms of procurement and inventory management costs.

The calculation of the optimal reorder point is accomplished through the statistical calculation module which scans the distribution table for the risk of stockout associated with the reorder level entered in the parameters section. The optimal reorder point is the lowest reorder point value which provides a risk value which does not exceed the target risk.

Enter the current reorder point and examine the comment box. If the comment **"WARNING!, This reorder point exceeds target risk. Risk of stockout is now: XXX%**, is illuminated, the value appearing in the current reorder level field should be raised to the lowest value which will cause the warning to disappear. If this vendor is selected as the new source, the first delivery order should be placed immediately upon contract award, in order to minimize the backorder situation

of the initial order cycle resulting from this vendor's production lead time. The quantity required in the initial delivery order will be the optimal order quantity plus the difference between the current inventory position and the new reorder point.

If, for the current reorder point, the warning is not illuminated, as in the case when the new vendor's production lead time is less than the incumbent vendor's, decrease the current reorder point field one unit at a time until the warning appears. At that point, increase the value by 1. The warning will disappear. This is the optimal reorder point for the new vendor.

5. Calculation of the optimal lot size

There are the two scenarios to consider when determining the optimal lot size. One is the single price bid, and the other is the multiple price range bid.

a. Single price range bids

This is the simpler of the two scenarios. As mentioned earlier, the prices are identical for the entire range of the bid. After parameter and vendor data are entered, the user must examine the four price fields appearing on the monitor to the right of the quantity and price fields, (see Appendix A) and identify the bid's lowest lot size. This is the starting point for the iterative procedure for determining optimal Q. The user checks to see that Q is set at this minimum quantity.

The total expected annual costs for this Q will appear on the screen after a short pause. The user should note the associated total costs value. Next, the Q value should be increased by one unit. If the expected total annual costs then increase, the value should be returned to the previous value. This value of Q is then the optimal lot size and provides the "best value" for the bid price and lead time. If, instead, the total annual costs decrease when Q is increased by one unit, the user should continue to increase Q by one unit until the total costs increase. As soon as that happens, the user should return to the preceding lot size value and stop. This is the optimal Q for this vendor. Finally, if the expected total annual costs continue to decrease until Q is equal to the average annual demand, then optimal Q is equal to the annual demand. Once optimal Q has been determined, its value must be entered into the Min Qty* location on the top line in preparation for calculating all the values needed on the final bid evaluation worksheet.

b. Price break bids

This calculation is a little more difficult. Of the upper three quantity/price fields, select the one with the lowest unit price. The quantity entered should be the minimum quantity qualifying for this price. After observing the expected total annual cost for this lot size, increase the lot size iteratively by one unit to determine the minimum expected

total annual costs for this price range. If that minimum cost lies at other than the minimum or maximum lot size within that range, stop. This is the optimal lot size. If the expected total annual cost at this unit price range occurs at either end of the price range, record the least total costs value and its lot size and repeat the above procedure with the range of lot sizes associated with the next lowest unit price. When a least total costs lot size is found between the lot size bounds of a price range, stop. Record that lot size and total costs and compare its total costs with those of the previous (lower unit costs) results. The lot size giving the least total costs from this comparison is the optimal lot size. Repeat the above steps as necessary. If all unit costs lot size ranges have their minimum total cost at the minimum quantity for the range, then compare all the minimum total costs to decide which minimum quantity value represents the optimal lot size. Finally, enter this quantity and price in to the upper quantity/price fields for printing.

c. Printing out the bid evaluation worksheet

Once the optimal reorder point and lot size has been determined and the optimum lot size and its corresponding unit price have been entered in the top Price/Quantity field, the user is ready to print the Bid Evaluation Worksheet in LOTUS WYSIWYG. If the user has failed to enter the optimal quantity and price, he or she will be prompted to do this by warning in

the comment box: **"CAUTION, possible Error! Lowest cost lot size must be entered in Min Qty* block."**

H. WORKSHEET ANALYSIS

Appendix A is an example of a completed bid evaluation worksheet. It contains the parameters, nomenclature, lead time, vendor bid, and analysis sections. It represents a breakdown of expected cost components associated with the optimal price and order quantity for this vendor. Besides the calculation of the expected total annual costs (shown as Rel. Costs), there are a few other valuable entries in the analysis section to compare with the other vendors.

1. Service level

The steady-state service level provided during the life of the contract has been established through the revision of the reorder point and lot size. However, if the current inventory position is significantly below the new optimal reorder point, the probability of stockouts during the first order cycle will be greater than after the initial order (which will consist of the optimal Q plus the difference between the reorder point and the current inventory position) is received. The initial order size is shown on the Worksheet. If it is greater than the optimal order quantity, then this should signal the potential for a serious stockout problem during the procurement lead time. For critical items, it may be advisable to expedite the initial shipment by using a resource

such as RAMP to lessen the severity of the initial stockout situation.

2. Shortage cost and backorder cost rate

The shortage cost is the *implied* cost of maintaining a requisition purchased from that particular vendor in a backordered status for an entire year. The backorder cost rate is independent of the vendor's price or customer requisition size and is provided for comparison to the holding cost rate. With a target risk as low as ten percent, the backorder cost rate should be much larger than the holding cost rate. Appendix A shows a backorder cost rate of 2.07 for vendor #1. In contrast, the holding cost rate was .23.

V. ILLUSTRATIVE EXAMPLE PROBLEM

A. PURPOSE

In order to demonstrate the utility of the model, an example problem which encompasses most of the functions of the model is provided. This example demonstrates the process for determining the optimal reorder point and lot size. It is a typical quantity discount bid evaluation having a current inventory position above the current reorder point based on a previous procurement. The current vendor in this case continues to offer a fixed pricing policy. In the example, a new vendor proposes a production lead time which is shorter than the incumbent vendor as well as price breaks for larger lot sizes.

Accompanying each step in the process will be a description of the algorithm performed by the model.

The vendor with the lowest total annual cost is vendor #1 on the data input sheet (Acme Valve Co.). We will analyze the model using the results for this vendor. The incumbent's optimal reorder point remains at 38, with an optimal lot size of 3, while the new vendor's reorder point can be reduced to 36, with an optimal lot size of 11.

B. BID DATA ENTRY

The first step is to develop the information needed by the Bid Evaluation Worksheet Data Input Sheet. The Bid Evaluation Worksheet Data Input Sheet for this example is shown on the following page. The top section has been prepared by the item inventory manager. The contracting office then adds bid information. The next step is to enter that information into the computer. Once that is done, determination of the optimal reorder point and lot size for each vendor can begin.

BID EVALUATION WORKSHEET DATA INPUT SHEET

Item description: _Valve________________________

NIIN:__00-987-65432_____________________________

Quarterly demand:__3.2_________ Current ROP:____38__________

Current inv. pos.__50__________ Essentiality (opt):____1____

Award Cost:_____750____________ Del. order cost:____50______

Holding cost rate:_____.23_____ Target risk:____.10________

Avg. reqn. size:_______1_______

Vendor #1

Name: ___Acme Valve Co._________________________________

Min. lot size:___3____________ Max. lot size:____30_______

QTY:____3-5___________________ Price:______$3650__________

QTY:_____6-10_________________ Price:______$3500__________

QTY:_____11-30________________ Price:______$3350__________

Procurement lead time:__9.35 qtrs__

Vendor #2

Name:___Incumbent Valve Co.______________________________

Min. lot size:___2____________ Max. lot size:___15________

QTY:___2-15___________________ Price:____3465_____________

QTY:__________________________ Price:_____________________

QTY:__________________________ Price:_____________________

Procurement lead time:_10 qtrs_____

C. DETERMINATION OF THE OPTIMAL REORDER POINT

The Poisson distribution table is constructed by the model using a calculated procurement lead time demand (μ) of 29.92 units based on the procurement lead time for vendor #1. The probability that the actual lead time demand (LTD) will be any particular value (x) is a function of the average LTD. The Poisson distribution calculates that probability as:

$$p(LTD=x) = \frac{\mu^x e^{-\mu}}{x!}.$$

The cumulative probability that the lead time demand will be equal or less than the reorder point (R) is therefore:

$$P(LTD\leq R) = \sum_{x=0}^{R} \frac{\mu^x e-\mu}{x!}.$$

This is the service level afforded by the reorder point R. The target risk was defined earlier as one minus the service level. In Chapter III, we defined P(x) as the probability that lead time demand will be equal to or greater than x. Employing that same terminology:

$$P(R+1) = \mathit{TARGET\ RISK} = 1-P(LTD\leq R)$$

The @VLOOKUP command determines the probability of stockout for the current reorder level of 38 entered in the parameters

section. Examining a portion of the Poisson distribution table for μ = 29.92 units, we see that the current reorder point of 38 units offers a stockout risk of 0.0448, which is much less than 0.10, which is the desired value of target risk. Therefore the user is asked to reduce the value of R in the solution process. By performing this iterative process of lowering the value entered in the current reorder level field, the user identifies the optimum reorder level, in this case, 36.

R	$P(LTD \geq R+1)$
33	0.198485552
34	0.153783025
35	0.116630258
36	**0.086586723**
37	0.062931393
38	0.044783508
39	0.031208891
40	0.021302731

For any new reorder point candidate less than 36 the model will recognize that the risk of stockout exceeds the target risk of .10. When this is the case, the risk warning illuminates and the user should then increase the R value until the warning ceases.

As the user becomes more experienced, he or she may simply scroll down to the statistical analysis section to observe lowest reorder point which satisfies the target risk parameter.

Ordering when the inventory position reaches 36 will result in the lowest ordering and holding cost which still protects the required service level of .90 for this prospective vendor. The actual service level will be 0.9134 for vendor #1.

D. DETERMINATION OF OPTIMAL LOT SIZE

The lot size corresponding to the lowest expected total annual cost given the optimal reorder point is the optimal lot size. Therefore, this process involves the calculation of expected inventory values, assignment of cost rate factors, and ultimately the summation of the four components of the expected total annual cost. The four statistical calculation modules provide for evaluation of up to four different price-break lot sizes.

The optimal lot size for each competing vendor is determined iteratively. Because of the importance of the lot size in the calculations of expected values for ordering costs and on-hand and backordered inventory levels and costs, the model performs several recalculations during each iteration.

The calculations described below illustrate those when the optimal reorder point, R, is 36. The result is an optimal lot

size, Q, of 11. The generation of expected unit-years backordered and unit-years on-hand will be addressed first for these values of R and Q. Recall from Chapter II that the expected unit-years backordered is calculated as follows:

$$B(Q,R) = \frac{1}{Q}[\beta(R) - \beta(R+Q)],$$

where

$$\beta(v) = \frac{\mu^2}{2}P(v-1;\mu) - \mu vP(v;\mu) + \frac{v(v+1)}{2}P(v+1;\mu).$$

The model uses the @VLOOKUP command to find the appropriate cumulative probabilities corresponding to the values of R and R+Q selected during each iteration. Inserting R=36 and R+Q=47 for v, the formula for β(v) shown above yields[1]:

$$\beta(R) = \frac{29.92^2}{2}(.1985) - (29.92)(36)(.1538) + \frac{(36)(37)}{2}(.1166),$$

$$\beta(R) = .8758;$$

$$\beta(R+Q) = \frac{29.92^2}{2}(.0038) - (29.92)(47)(.0023) + \frac{(47)(48)}{2}(.0014),$$

$$\beta(R+Q) = .0044;$$

---

[1] For simplicity, the probabilities have been rounded to four decimal places. The values for β are those actually generated by the model using nine decimal places.

and, therefore,

$$B(Q,R)=\frac{1}{11}[.8758-.0044]=0.0792.$$

Now that the expected unit-years backordered has been determined, the expected unit-years on-hand (E[OH]) can be calculated using the following formula from Chapter II:

$$E[OH]=R+\frac{Q}{2}+\frac{1}{2}-\mu+B(Q,R)$$
$$E[OH]=36+\frac{11}{2}+\frac{1}{2}-29.92+.0792$$
$$E[OH]=12.1592.$$

After the time-weighted on-hand and backordered levels have been calculated, their related costs can be assigned. These costs are based on each bidder's unit cost and the parameters entered in the parameter fields at the top of the bid evaluation worksheet data input sheet.

<u>a. Annual holding costs</u>: The product of the holding cost rate (.23) and the unit cost ($3350.00), associated with the 11-30 lot size range from vendor #1, are now multiplied by the expected on-hand inventory in unit-years (12.1592) to get a total of $9368.67 per year.

<u>b. Annual backorder costs</u>: The expected units-years backordered (.0792) is multiplied by the unit cost ($3350.00), essentiality factor, and the backorder cost rate λ'. First,

however, λ' must be computed using the equation derived in Chapter III.

$$\lambda' = I\left(\frac{1}{RISK} - 1\right)$$
$$\lambda' = .23\left(\frac{1}{.1} - 1\right)$$
$$\lambda' = 2.07.$$

Then the annual backorder costs are:

$$\lambda' CE[BO] = (2.07)(3350)(0.0792) = \$549.28.$$

c. Ordering cost: This is the cost of contract award ($750.00) plus the sum of the expected costs of preparing each delivery order. The latter is determined as the product of the cost of delivery order preparation and average number of delivery orders per year. The total ordering cost is therefore:

$$K + A\frac{4D}{Q} = 750 + (50)\frac{(4)(3.2)}{11} = \$808.18.$$

d. Average annual procurement costs (Hardware costs): 12.8 units are expected to be demanded per year. When multiplied by the cost associated with the 11-30 lot size range of $3350.00 (from the worksheet for vendor #1) the total average annual procurement costs are $42,880.00.

e. Total average annual costs: The sum of the annual costs from the cost components are $53,606.14 for the new bidder,

and \$53,612.94 for the incumbent vendor (see Appendix A). Although vendor #1 has the lower total costs and is, theoretically, the "winner", it should be noted that the expected total annual costs for each vendor when Q and R are optimized are very close. The procurement should, in this case, probably should be awarded based on merits other than expected total annual cost, such as past performance.

E. CHOOSING THE OPTIMAL LOT SIZE WHEN PRICE BREAKS EXIST

The process of selecting the optimal lot size when price breaks exist is illustrated in this section. For the example problem, the following is a listing of total annual costs for each eligible unit price value from vendor #1.

Lot size	Total annual cost
3	$56,206
4	$56,329
5	$56,519
6	$54,459
7	$54,719
8	$55,005
9	$55,312
10	$55,635
11	$53,606
12	$53,937
13	$54,276.

When the price/quantity data was first entered, the lowest expected total annual cost of $53,606 was associated with the order quantity of 11 units at $3,350. Raising that quantity to 12 units increased the expected total annual cost to $53,937. Similarly, the lowest expected total costs were associated with 6 units in the 6-10 units range for the unit price of $3,500. Finally, the lowest expected total costs were associated with 3 units for the 3-5 units range for the

unit price of \$3,650. Comparing these three minimum total annual cost values resulted in an optimal Q of 11 since it corresponds to the lowest of these minimums.

The savings in holding and backorder costs for this particular procurement from vendor #1 can be as high as \$2,913 when selecting the optimum lot quantity rather than some other Q value in the allowed range for a given unit price. However, the changes in the total annual costs for changes in Q for a given unit price are very small when compared to the price break's effect on annual procurement costs. The values of the expected annual procurement costs, 4DC, for each price break are \$42,880, \$44,800, and \$46,720, for the lowest to the highest unit costs.

VI. SUMMARY, CONCLUSIONS, RECOMMENDATIONS

A. SUMMARY

This thesis was written in response to a request from the RAMP Program Office to develop a PC-based vendor evaluation model which would demonstrate the benefits of rapid production lead times. This model augments other research currently being conducted by the Naval Postgraduate School, and funded by RAMP, to determine RAMP's potential contribution to establishing a more effective and efficient procurement system.

The Department of Defense, by considering ordering, backordering, and holding costs prior to contract award can reduce its levels of required inventory while providing the same high level of service to its customers. For most secondary items, awards are based on hardware unit price only, and then that price and procurement lead time is passed to inventory control points where a new reorder point and order quantity must then be computed. These optimizations of R and Q are designed to minimize the future total annual costs of buying from that vendor. This thesis has attempted to show that considering only the lowest hardware cost can be deceiving.

Past suppliers to DoD have concluded that they can reduce costs and capture greater amounts of work by producing large lot sizes over long production lead times. The vendor gains by taking advantage of production economies of scale at the expense of higher holding and backorder costs to the government. Longer procurement lead times necessitate higher reorder points to prevent stockouts before replenishment arrives. The potential for items becoming obsolete is also higher. In contrast, shorter lead times reduce reorder points and allow for smaller order quantities. The risk of obsolescence is also reduced. This thesis has therefore attempted to quantitatively demonstrate the impact that procurement lead time has on the overall inventory management costs of secondary hardware items.

Chapters I, II, and III have presented the steps for adapting the UICP model into a model for determining best value. The Best Value Model enables a purchasing agency to compare all the cost components rather than just the unit cost when making a source selection for steady state, low demand items. It serves to quantify the costs associated with other important parameters such as procurement lead time and target risk. It provides calculations and documentation of both the *explicit* (hardware) and *implicit* (ordering, holding and backordering) costs of satisfying supply system requirements. Chapters IV and V have discussed the operation and the analysis provided by the Best Value Model for establishing

optimal reorder points and lot sizes, and then comparing vendor proposals. This thesis also provides a user's manual (Appendix D).

B. CONCLUSIONS

1. The Best Value Model

The Best Value Model is a stand alone, PC-based software program which can be used by management and non-management personnel for determining optimum reorder points and lot sizes which minimize the expected total annual costs already accepted by the Department of Defense (DODINST 4140.39, 1970). It is simple to operate and can rapidly evaluate each proposal. It also provides an evaluation worksheet for the procurement file.

2. The RAMP Program

Reducing production lead time lowers the annual inventory management costs. The most significant impact is from the reduction in the reorder point. The RAMP program can provide material within very short lead times. However, it could not quantify the cost savings of rapid delivery. RAMP is capable of providing these items very rapidly due to its application of high technology and significant investment in digitizing the item specifications for use in sophisticated flexible manufacturing processes. This usually results in higher unit prices for initial contracts, but significant savings can be realized in subsequent contracts (RAMP Interview, August

1993). Chapter I, however, recommends removing the initial set-up costs from the unit cost computation because of the stand-alone value of the reverse engineering effort performed by RAMP, and the resultant savings in the Navy Stock Fund from reducing the reorder point. RAMP can be competitive when the cost savings are argued from the standpoint of reduced lead times leading to reduced reorder points and hence the requisitioning objective (R+Q) which determines the stock fund corpus. It can also provide savings through its ability to produce smaller lot sizes than its competition.

3. RAMP competitive advantage

The RAMP program should argue its competitive advantage in providing rapid delivery in small lots of items that require several machine operations to complete. In addition to being considered as a cost effective routine source of supply, utilization of RAMP is especially valuable for the production of items which, for reasons of contractor default, recompetition, or other unusual reason have fallen significantly below the established reorder level in terms of inventory position. Items requiring a high service level require either large reorder points or short production lead times.

4. Consideration of Implied Costs

There are two opposing philosophies at work in the supply system. Inventory managers are directed by DODINST 4140.39 to

minimize explicit and implied costs (but nonetheless very real costs) in establishing optimum inventory levels, while procurement specialists are bound by the Federal Acquisition Regulations, which do not recognize implied costs as an evaluation criterion. For simple procurements of secondary hardware items, the consideration procurement specialists give is often only to the lowest hardware cost. To select a vendor other than that with the lowest unit cost requires justification. Some examples of justification include small business considerations, national security, and industrial base preservation issues (FAR, 1992). Consideration of implied shortage costs prior to contract award might change the decision on the vendor selected. The best value model or one similar to it could help to identify these implied costs.

C. RECOMMENDATIONS

1. Segregation of set-up costs

RAMP should be alert to the requirement for items it has provided in the past to the Item Manager. Having already invested set-up costs for these items, it can produce subsequent lots at a lower cost. For new bids, the cost of reverse engineering the drawings onto NC machine compatible media should be appropriately segregated from the unit cost. The cost of the reverse engineering effort can be paid for by reductions in the Navy Stock Fund.

2. Adoption of Target Risk

Other total annual cost models such as the UICP consumables model, FCIM-DSS, and Q star use a fixed value for the shortage cost, developed for each four-digit cognizance symbol by the CARES model to meet an annual goal of an 85 percent requisition fill rate. This fixed value is used as a parameter for determining the optimal risk of stockout and, consequently, the reorder point. This model requires the evaluation of inventory items with respect to criticality and the assignment of a required level of service, the compliment of which is target risk. Employing the target risk approach, a specific desired risk of stockout is determined by the ICP or item inventory manager and the Best Value model generates a different value for the implicit shortage cost for an item. Suggestions for determining appropriate target risks include CASREP analysis, other failure analysis, end item criticality, existence of redundancy and provision of baseline levels of protection for inventory items.

3. Alternative to Procurement

For critical items of extremely low demand, the government should consider procurement from the contractor of simply the NC drawings, which can be stored until fabrication of the item by a RAMP site. There is a potential for savings in storage and obsolescence costs (SPCC interview, October 1993).

4. Implementation

The Best Value Model should be tested jointly by an inventory management and procurement team. Implementation testing should include model validation, feasibility of implementation with respect to receptiveness by the agency and individual users, required needs for training, and interface with the Federal Acquisition Regulations. The FAR does not currently recognize implied costs as an evaluation criterion. In addition, contracts awarded based on rapid delivery rather than lowest price are usually justified by extraordinary urgency, rather than overall best value to the government. Problem areas relative to the FAR and the procurement arena could include an increased likelihood of award protests and a slight increase in contractual actions involving best and final offers.

Once the FAR issues have been resolved, the model should be examined by the Naval Supply Systems Command for consideration and, if approved, it would become the accepted model for vendor selection, subject to the limitations applications defined in Chapter IV. A similar model may be developed for use by DLA, as the migration of most consumable secondary hardware items progresses. This is an appropriate follow-on thesis topic.

LIST OF REFERENCES

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APPENDIX A: BID EVALUATION WORKSHEET

This appendix contains the Bid Evaluation Worksheets generated as a result of the example problem. It is also referred to throughout the thesis as a sample of the output generated by the model.

The two bid evaluation worksheets represent the results of a competition between two vendors for a secondary hardware item. One offers a fixed pricing scheme, while the other offers a quantity discount. The optimization procedures are described in Chapter IV of the thesis.

BID EVALUATION WORKSHEET

PARAMETERS:

3.2	Quarterly Demand	150	Admin lead time (days)
38	Current Reorder Level	760	Bid lead time (days)
50	Current Inv. Position		
1	Essentiality	ITEM	Valve
1	Avg. Units/reqn	NIIN	00-987-6543
$750	Award Cost	VENDOR	Incumbent Valve Co.
$50	Delivery order cost		
0.23	Holding cost rate		
0.1	Target Risk		

VENDOR BID INPUTS:

3	Min. Qty*	$3,465.00	Price	$53,612.94	Rel. Cost
6	Min. Qty	$3,465.00	Price	$54,052.77	Rel. Cost
10	Min. Qty	$3,465.00	Price	$55,153.08	Rel. Cost
13	Max. Qty	$3,465.00	Price	$56,149.71	Rel. Cost

COMMENTS:

ANALYSIS SECTION

ORDERING CS	$963.33
HOLDING CST	$6,567.80
BO CST	$1,729.80
H/W CST	$44,352.00
TOTAL CST	$53,612.94
SERVICE LEVE	90.44%

SHORTAGE CS	$7,172.55	OPT QUANTITY	3
BO CST RATE	2.0700	OPT PRICE	3465
		OPT ROP	38
		ROP+Q	41
		WAIT (QTRS)	3.75
		INT ORDER	3

EXPECTED UNITS ON HAND	8.241170005
EXPECTED UNIT YEARS BACKORDERED:	0.241170005

14-Dec-93

BID EVALUATION WORKSHEET

PARAMETERS:

3.2	Quarterly Demand	150	Admin lead time (days)
38	Current Reorder Level	760	Bid lead time (days)
50	Current Inv. Position		
1	Essentiality	ITEM	Valve
1	Avg. Units/reqn	NIIN	00-987-6543
$750	Award Cost	VENDOR	Incumbent Valve Co.
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TOTAL CST	$53,612.94
SERVICE LEVE	90.44%

SHORTAGE CS	$7,172.55	OPT QUANTITY	3
BO CST RATE	2.0700	OPT PRICE	3465
		OPT ROP	38
		ROP+Q	41
		WAIT (QTRS)	3.75
		INT ORDER	3

EXPECTED UNITS ON HAND 8.241170005
EXPECTED UNIT YEARS BACKORDERED: 0.241170005

14-Dec-93

APPENDIX B: SPCC SHORTAGE COSTS AND RISK RANGES

This is the list of risk values and shortage costs used by the Ship's Parts Control Center (SPCC) for each four-digit cognizance symbol consumable managed by SPCC. The shortage values are generated by CARES, which uses different SMA goals to determine the dollar value of the shortage cost. The total overall goal is 85 percent SMA. This concept is explained in detail in Chapter VI.

UCED AT GC'' RNMENT EXPENSE

LEVELS PARAMETERS

SEP 92

D01/PD82

COG	MIN RISK	MAX RISK	SHORT COST	PROB BP	R L CNST	MAX QTR SL	COG	MIN RISK	MAX RISK	SHORT COST	PROB BP	R L CNST	MAX QTR SL	COG	MIN RISK	MAX RISK	SHORT COST	PROB BP	R L CNST	MAX QTR SL
DFLT	0.01	0.99	0.03	20	0	20														
1H	0.10	0.99	400.00	20	0	20														
1H4A	0.10	0.35	1,000.00	0	1	20	1H4B	0.10	0.40	750.00	0	1	20	1H4C	0.10	0.50	400.00	0	1	20
1H3A	0.10	0.35	1,000.00	0	1	20	1H3B	0.10	0.40	750.00	0	1	20	1H3C	0.10	0.50	400.00	0	1	20
1H2A	0.10	0.35	1,000.00	0	1	20	1H2B	0.10	0.40	750.00	0	1	20	1H2C	0.10	0.50	400.00	0	1	20
1H1A	0.10	0.35	1,000.00	0	1	20	1H1B	0.10	0.40	750.00	0	1	20	1H1C	0.10	0.99	400.00	20	0	20
1H0A	0.10	0.35	1,000.00	0	1	20	1H0B	0.10	0.40	750.00	0	1	20	1H0C	0.10	0.99	400.00	20	0	20
1H4D	0.10	0.35	1,000.00	0	1	20	1H4E	0.10	0.40	750.00	0	1	20	1H4F	0.10	0.50	400.00	0	1	20
1H3D	0.10	0.35	1,000.00	0	1	20	1H3E	0.10	0.40	750.00	0	1	20	1H3F	0.10	0.50	400.00	0	1	20
1H2D	0.10	0.35	1,000.00	0	1	20	1H2E	0.10	0.40	750.00	0	1	20	1H2F	0.10	0.50	400.00	0	1	20
1H1D	0.10	0.35	1,000.00	0	1	20	1H1E	0.10	0.40	750.00	0	1	20	1H1F	0.10	0.99	400.00	20	0	20
1H0D	0.10	0.35	1,000.00	0	1	20	1H0E	0.10	0.40	750.00	0	1	20	1H0F	0.10	0.99	400.00	20	0	20
1HN1	0.10	0.35	1,500.00	0	1	20	1HS1	0.10	0.35	2,500.00	0	1	20							
1HN2	0.10	0.35	1,500.00	0	1	20	1HS2	0.10	0.35	2,500.00	0	1	20							
1HN3	0.10	0.35	1,500.00	0	1	20	1HS3	0.10	0.35	2,500.00	0	1	20							
1H4P	0.50	0.50	0.03	0	1	0														
1H3P	0.50	0.50	0.03	0	1	0														
1H2P	0.50	0.50	0.03	0	1	0														
1H1P	0.50	0.50	0.03	0	1	0								1H1Q	0.10	0.99	400.00	20	0	0
1H0P	0.50	0.50	0.03	0	1	0								1H0Q	0.10	0.99	400.00	20	0	0
3H4A	0.10	0.99	400.00	20	0	20														
3H4A	0.10	0.35	1,000.00	0	1	20	3H4B	0.10	0.40	750.00	0	1	20	3H4C	0.10	0.50	400.00	0	1	20
3H3A	0.10	0.35	1,000.00	0	1	20	3H3B	0.10	0.40	750.00	0	1	20	3H3C	0.10	0.50	400.00	0	1	20
3H2A	0.10	0.35	1,000.00	0	1	20	3H2B	0.10	0.40	750.00	0	1	20	3H2C	0.10	0.50	400.00	0	1	20
3H1A	0.10	0.35	1,000.00	0	1	20	3H1B	0.10	0.40	750.00	0	1	20	3H1C	0.10	0.99	400.00	20	0	20
3H0A	0.10	0.35	1,000.00	0	1	20	3H0B	0.10	0.40	750.00	0	1	20	3H0C	0.10	0.99	400.00	20	0	20
3H4D	0.10	0.35	1,000.00	0	1	20	3H4E	0.10	0.40	750.00	0	1	20	3H4F	0.10	0.50	400.00	0	1	20
3H3D	0.10	0.35	1,000.00	0	1	20	3H3E	0.10	0.40	750.00	0	1	20	3H3F	0.10	0.50	400.00	0	1	20
3H2D	0.10	0.35	1,000.00	0	1	20	3H2E	0.10	0.40	750.00	0	1	20	3H2F	0.10	0.50	400.00	0	1	20
3H1D	0.10	0.35	1,000.00	0	1	20	3H1E	0.10	0.40	750.00	0	1	20	3H1F	0.10	0.99	400.00	20	0	20
3H0D	0.10	0.35	1,000.00	0	1	20	3H0E	0.10	0.40	750.00	0	1	20	3H0F	0.10	0.99	400.00	20	0	20
3HN1	0.10	0.35	1,500.00	0	1	20	3HS1	0.10	0.35	2,500.00	0	1	20							
3HN2	0.10	0.35	1,500.00	0	1	20	3HS2	0.10	0.35	2,500.00	0	1	20							
3HN3	0.10	0.35	1,500.00	0	1	20	3HS3	0.10	0.35	2,500.00	0	1	20							
3H4P	0.50	0.50	0.03	0	1	0														
3H3P	0.50	0.50	0.03	0	1	0														
3H2P	0.50	0.50	0.03	0	1	0														
3H1P	0.50	0.50	0.03	0	1	0								3H1Q	0.10	0.99	400.00	20	0	0
3H0P	0.50	0.50	0.03	0	1	0								3H0Q	0.10	0.99	400.00	20	0	0

APPENDIX B

1

APPENDIX C: BID EVALUATION WORKSHEET DATA INPUT SHEET

This is the Bid Evaluation Worksheet Data Input Sheet, from which the item and vendor information is entered into the model. The data comprising the upper portion of the sheet is provided from the item inventory manager, who uses information obtained from the Master Data File (MDF) as well as policy currently in force at the Inventory Control Point (ICP).

Procurement personnel enter vendor bid information on the lower portion of the input sheet. This speeds the evaluation process. This sheet should be retained in the procurement documentation file.

BID EVALUATION WORKSHEET DATA INPUT SHEET

Item description: ______________________________

NIIN: ____

Quarterly demand: _________________ Current ROP: ________________

Current inv. pos: _________________ Essentiality (opt): _________

Award Cost: _______________________ Del. order cost: ____________

Holding cost rate: ________________ Target risk: ______________

Avg. Reqn. size: __________________

Vendor #1

Name: ____

Min. lot size: ____________________ Max. lot size: _____________

QTY: ______________________________ Price: ____________________

QTY: ______________________________ Price: ____________________

QTY: ______________________________ Price: ____________________

Procurement lead time: _____________

Vendor #2

Name: ____

Min. lot size: ____________________ Max. lot size: _____________

QTY: ______________________________ Price: ____________________

QTY: ______________________________ Price: ____________________

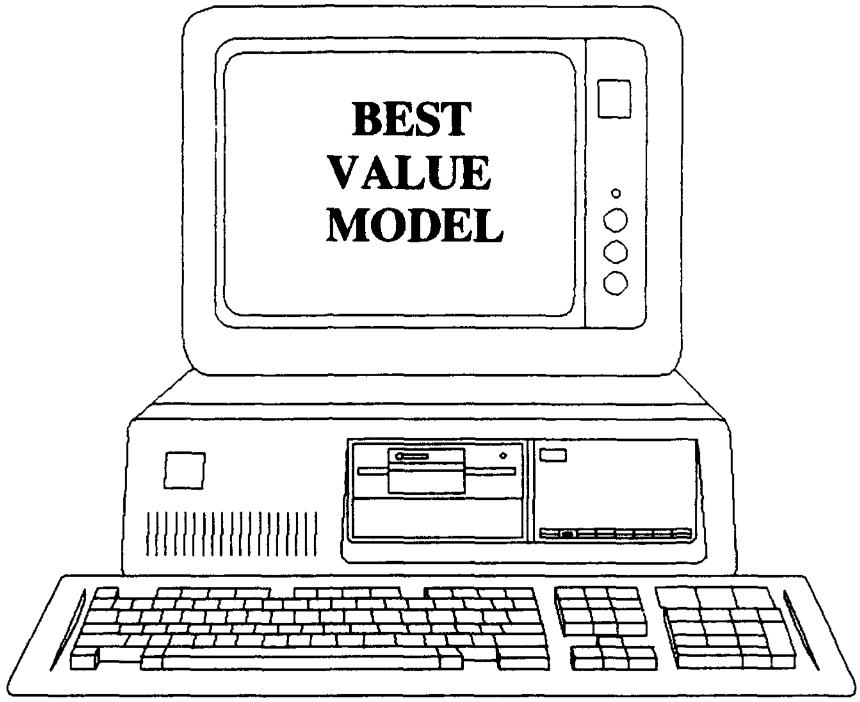
QTY: ______________________________ Price: ____________________

Procurement lead time: _____________

APPENDIX D: THE BEST VALUE MODEL USER'S MANUAL

This is the user's manual for the Best Value Model. It contains a brief overview of the model, and step by step procedures for conducting the optimization process.

It is written at a lower level than the thesis itself in order to facilitate use by procurement personnel and inventory managers. It provides pictures to compare the user's results to the sample problems, and contains two completed bid evaluation worksheets which should be identical to those generated by the user in the tutorial section of the user's guide.



A PC-BASED, DECISION SUPPORT SOFTWARE PROGRAM DESIGNED FOR EVALUATION OF VENDOR PROPOSALS

LCDR Arthur B. Horsley
Naval Postgraduate School
December 17, 1993

I. The Best Value Model User's Manual

A. Introduction

The Best Value Model is a proposal evaluation decision support software program, designed to aid source selection personnel in determining the competing vendor who can provide the best value to the government in terms of lowest expected total annual costs. Total expected annual costs can be minimized by choosing the proper reorder point and lot size.

The total annual costs have four components:

1. Procurement (Hardware) costs: This is the total expected annual requirement for the item under consideration multiplied by the proposed unit cost provided by the vendor. Procurement cost is the component commonly referred to by contracting personnel as the contract cost, that which must not be exceeded on the funding document. If the competition for the item specifies a maximum affordable cost, then the procurement cost component is that which must be at or under the limit.

2. Ordering costs: These are the costs of performing the administrative functions associated with conducting the competition, contract award, and preparation of delivery orders throughout the year. While designed for use with Indefinite Delivery/Indefinite Quantity (IDIQ) contracts, the model can also be used for other contract types.

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3. Holding costs: These are the costs associated with holding the item in inventory after receipt from the vendor and prior to issue to the end user.

4. Backorder costs: These are the costs of maintaining units in a backordered status. These costs are analogous to holding costs, with the exception that the material is required by the end user prior to the inventory system receiving an order.

The ordering costs, holding costs, and backorder costs are not paid for by the customer directly, and are therefore are not included in the contract price. All of the above cost components are, however, calculated automatically by the model and, by performing the optimization procedure, the user can determine the best value, as measured by the total expected annual costs, a vendor can offer the government.

B. Limitations

This model is designed to evaluate procurements of only certain types of material requirements. If used for other than the categories specified below, the results will be invalid. Source selection personnel should carefully consider the following limitations prior to employing the model.

1. The average quarterly demand should vary randomly: This means that the demand should not be absolutely firm over the next four quarters and should not be dependent on the previous quarter's demand. Those items expected to have firm planned requirements accounting for more than approximately 25 percent

of the total anticipated demand, such as outfitting items or shipyard planned repair requirements should not be evaluated using this model. The 25 percent figure is a general guideline which serves to ensure that the probability distribution used by the model is appropriate to the application.

2. The item should have a steady state demand probability distribution: The average demand for the item should be fairly constant over the next four quarters. While the program is designed to accommodate low to moderate demand fluctuations, sharply increasing or decreasing demand trends, or highly erratic demand spikes indicate that the item is not a good candidate for this program. Any particular quarter demand figure should not vary from the average quarterly demand by more than an amount equivalent to this average value.

3. The expected lead time demand must be equal to or less than 50 units: The lead time demand is the product of the item's average quarterly demand and the procurement lead time (in quarters). Because the Poisson probability distribution is used in this model for demand during lead time, the user will experience a loss of accuracy if the lead time demand exceeds 50 units. The Poisson probability distribution is that which best approximates low to moderate demand patterns. Demand beyond this low to moderate level would require a different probability distribution such as the normal distribution.

C. Calculation of total annual costs

The program calculates the expected annual value of inventory on-hand and inventory backordered as a function of the reorder point and the order quartity. It then calculates the costs of both using the item parameters. The resulting cost components described in section A are then totaled, giving the user an expected total annual costs. These costs can be compared to that of other competing vendors. The vendor with the lowest expected total annual costs should be considered a preferred source of supply.

D. Types of procurement competitions

The Best Value model is capable of evaluating proposals having a single unit price, or proposals employing a quantity discount. The procedures for calculating the lowest expected total annual cost using the model are included for each type of procurement scenario.

E. Hardware and Software requirements

The Best Value model is a spreadsheet program designed to run on LOTUS 123 or equivalent software applications. Results are best when using the WYSIWYG (**W**hat **Y**ou **S**ee **I**s **W**hat **Y**ou **G**et) add-in, which is included in the recent LOTUS 123 (Releases 2.2 and higher). It may be run on any IBM compatible computer capable of running LOTUS 123 (with or without Windows), and

should be loaded to the hard drive as a subdirectory, allowing the user to maintain the floppy version as a backup.

The spreadsheet is protected against inadvertent entry through a global protection function which allows entries only in valid fields. This will prevent any accidental degradation of the program.

II. Bid Evaluation Procedures

The expected total annual cost can be minimized by first determining the optimal reorder point and then the optimal order quantity. These optimal values are a function of many factors including procurement lead time, unit cost, ordering cost, and desired risk of stockout. The procedures described below give the general directions for using the Best Value model to calculate the optimal reorder point and lot size. This section is followed by an example problem.

When the Bid Evaluation Worksheet Data Input Sheet is received from the item inventory manager, the top portion should already be filled in. Contracting personnel must then fill in the vendor bid data on the lower part of the form.

Step 1: Item parameter and bid price/range data entry: From the Bid Evaluation Worksheet Data Input Sheet, enter the item name, NIIN, and vendor name for vendor proposal #1 in the nomenclature field. Next, enter the item parameters into the appropriate fields appearing on the monitor screen. These fields include:

Quarterly demand

Current Reorder level

Current Inventory position

Average units/requisition

Essentiality

Award Cost

Delivery Order Cost

Holding Cost Rate

Target Risk[1]

Finally, enter the procurement lead time (administrative lead time plus the bid production lead time) in the lead time section.

In the vendor bid inputs section, enter the appropriate prices in the four price fields. Some proposals will cite one uniform price regardless of lot size, while others will provide quantity discounts. The Best Value model can accommodate either scenario. In the top quantity field (Min. Qty*), enter the minimum lot size allowed by the vendor. For single price bids, enter values in the remaining two fields that serve to divide the quantity rang into three ranges of approximately equal size. This will aid in the iterative process of determining the optimal lot size. In the case of quantity discount pricing, enter the minimum lot size qualifying for each price, and the corresponding unit price. Disregard lot sizes larger than the total annual demand which appears in the Max. Qty field. The maximum lot size will

[1] Target risk is the risk of stockout most appropriate for this item. For a complete description of target risk, see Chapter IV of the thesis entitled A Model for Evaluating Vendor Proposals for Price and Lead Time; Arthur B. Horsley, Naval Postgraduate School, December 1993.

appear automatically in the bottom quantity field (Max. Qty). The maximum quantity is equal one year's worth of demand, rounded to the nearest unit. The expected total annual costs for the minimum order quantity of each price field is calculated automatically and appears in the relevant cost field (Rel. Cost) to the right of its associated quantity and price.

Step 2: Determining the optimal reorder point: This procedure involves adjusting the current reorder level field inside the parameters section on the screen. Examine the comment box. If the warning: **"WARNING! The reorder point exceeds target risk. Risk of stockout now XXX%"** is illuminated, the reorder point currently stored in the Master Data File (MDF) will not satisfy the required service level required of this item, and the reorder point value must be raised. Put the cursor on the current reorder level field of the parameters section, and raise the value of the field one unit at a time until a number is entered which causes the risk warning to disappear. This is the revised optimal reorder point.

If the risk warning is not initially illuminated, the current reorder point may need to be adjusted downward. Lower the value of the number appearing in the current reorder level field by one unit at a time until a value is reached which illuminates the warning. Then raise the reorder level by one unit. This is the optimal reorder level.

Step 3: Determination of optimal lot size:

A. Single price range bids

This calculation is performed in the top line of the vendor input section. Starting with the smallest allowable order quantity, examine the expected total annual costs (shown in the Rel. Cost field). Take a note of this value. Increase the order quantity by one unit. If the expected total annual costs increase, return the order quantity value to its previous value. This is the optimal order quantity. If, instead, the expected total annual costs decrease when the order quantity is increased by one unit, then continue to increase the value of the order quantity by one unit until the expected total annual costs start to increase. As soon as this happens, return to the preceding order quantity value and stop. This is the optimal order quantity. If the expected total annual costs continue decreasing up to the expected total annual demand (shown in the bottom (Max Qty) field), then that is the optimal order quantity.

B. Determining the optimal lot size for bids employing quantity discounts

Examine the upper three quantity/price rows and select the row with the lowest unit price. Recall that the order quantity entered to the left of this unit price should be the minimum order quantity qualifying for this price. After

noting the expected total annual costs for this order quantity, iteratively increase the value of the order quantity by one unit as in the single price scenario to determine the order quantity which minimizes expected total annual costs for this price. If that minimum cost lies at other than the minimum or maximum lot size within that price, stop. This is the optimal order quantity. If the expected total annual cost at this lowest unit price occurs at either end of the quantity range, retain that quantity on the screen and scroll to the next lowest unit price row and repeat the procedure. When a least total costs order quantity is found between the lot size bounds of a price, stop. Compare the expected total annual cost fields that have previously been minimized. The row with the lot size and unit price which results in the lowest expected total annual cost is optimal. Finally, enter this quantity and price in the upper quantity/price fields for printing.

Step 4: Printing the Bid Evaluation Worksheet: After the lowest total annual cost has been attained for the vendor, enter the WYSIWIG print menu, and set the print parameters for the particular printer in use. Preview the document to ensure that the entire Bid Evaluation Worksheet appears. The worksheet will appear with all the relevant data and date printed for inclusion in the procurement file.

III. Bid Evaluation Worksheet Analysis and Award Criteria

Once every eligible vendor has been evaluated, the worksheets can be compared with respect to cost and service level.

Note: This program is not intended to be the only tool in source selection. There may be other factors such as industrial base preservation issues, small business considerations and performance of the vendor in previous procurements which may be important to consider prior to contract award.

A. Total annual costs

Examine the printed bid evaluation worksheets. Find the vendor with the lowest expected total annual costs. This is the vendor who offers best value in terms of expected total annual costs. If the procurement (hardware) cost component of the total annual cost is within the range of affordability, (ceiling on contract price), and the other selection criteria mentioned above do not exclude this vendor, award the contract to this vendor, and issue the delivery orders in accordance with the instructions in the analysis section of the worksheet. The analysis section provides the revised reorder point, unit price, optimal order quantity, the value of the

initial order quantity, and the estimated wait until the first delivery order should be issued.

B. If the winning vendor is outside the range of affordability

If the winning vendor's procurement costs, as defined in Section A of Chapter I, exceed the obligational authority of this procurement, this situation will require the issuance of a best-and-final offer. The item manager will have to compromise the level of service to meet budgetary constraints. Issue a best-and-final Request For Quotation (RFQ) to interested vendors, allowing them to price their items for receipt at the lead time bid by the vendor with the shortest lead time that was also within the realm of affordability. This action allows the vendors with shorter production lead times to relax their production lead times in order to reduce their unit costs. Reevaluate the resultant RFQs, and select the vendor offering the best value at the revised service level.

IV. Example problem

The following is an example involving the comparison of a single price range bid and a quantity discount bid. It is advisable that the new user perform the analysis while following along in the manual.

This example was chosen to demonstrate the advantage of shorter lead times in reducing total annual costs, and improving the level of service by reducing the probability of stockouts. This is a hypothetical example devised for illustrative purposes.

Refer to the following bid evaluation worksheet data input sheet to begin the analysis:

BID EVALUATION WORKSHEET DATA INPUT SHEET

Item description: __Flange________________________

NIIN:_011234567___________________________________

Quarterly demand:_____5___________ Current ROP:____42______

Current inv. pos:____20___________ Essentiality (opt):___1_

Award Cost:________750____________ Del. order cost:___75___

Holding cost rate:__.23___________ Target risk:_____.10___

Avg units/reqn:______1____________

Vendor #1

Name: _______ABC INC.________________________________

Min. lot size:______5_____ Max. lot size:____20____

QTY:___5-20_______________ Price:____$2950.00_________

QTY:______________________ Price:_____________________

QTY:______________________ Price:_____________________

Procurement lead time:__6.5 QTRS___

Vendor #2

Name: ____DEF INC.____________________________________

Min. lot size:_____1________ Max. lot size:___50________

QTY:______1-3_______________ Price:______$3500.00_______

QTY:______4-10______________ Price:______$3250.00_______

QTY:______11-50_____________ Price:______$3000.00_______

Procurement lead time:__1.5 QTRS___

Step 1. Unit parameters entry: Use the Bid Evaluation Worksheet Data Input Sheet to fill the item parameters fields. This information must be provided by the item manager. Note that with the exception of the reorder level field, this data will remain unchanged throughout all the vendor bid evaluations.

Parameters:

5	Quarterly Demand
42	Current Reorder Level
20	Current Inventory Position
1	Essentiality
1	Avg. Units/Requsition
$750	Award Cost
$75	Delivery Order Cost
0.23	Holding Cost Rate
0.1	Target Risk

Figure 1. Item parameters section.

Quarterly demand: This is the average quarterly demand for the item.

Current reorder level: This is the reorder point currently established for the item by UICP.

Current inventory position: This is the current inventory position (on-hand plus on-order minus backorders) of the item.

Essentiality: This is a number between zero and one, which is used to weigh the essentiality of items within the same category. The default entry is one (1).

Award cost: This is the cost associated with the administrative workload of source selection and contract award. This amount will vary depending on the type of competition used.

Delivery order cost: This is the administrative cost of issuing each delivery order. A delivery order is issued whenever the inventory position reaches the reorder point specified by the model. This cost should be significantly

less than the award cost. If for any reason this is not the case, the contract should be recompeted every time the inventory position reaches the reorder point.

Holding cost rate: This is the cost of maintaining material in inventory. The UICP rate for consumables is currently .23, and is specified by the Inventory Control Point (ICP).

Target risk: This is the risk of stockout determined by the item manager to be optimal for this item. For example, a target risk of .10 means that for 90 percent of the order cycles all requisitions should be able to be filled from stock on-hand.

Step 2: Entry of vendor bid data: This involves filling the fields specifically for vendor #1. The first part of this step is to fill out the lead time section and then the item nomenclature section:

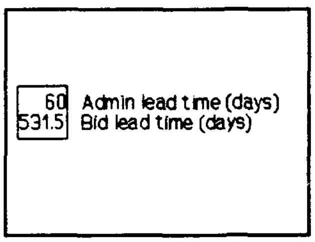

Figure 2. This is the lead time for vendor #1.

Admin lead time (days): The estimated number of days required to administratively process this procurement from the time the inventory position was reduced to the current reorder point to the time of contract award.

Bid lead time (days): The production lead time proposed by the competing vendor is entered in this block. This must be in days. The user may use the spreadsheet function to simplify the conversion process. If the vendor bids delivery in 8

weeks, the entry for this cell can be 8x7 or 56. If he bids 2.5 quarters, the entry is 2.5x91 or 227.5.

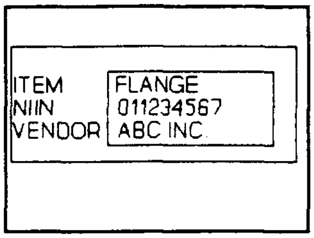

Figure 3. Nomenclature fields for vendor #1.

Item nomenclature: Complete these fields for later comparison and addition to the procurement file.

Vendor bid inputs: Enter the minimum quantity that vendor #1 is willing to produce in a lot in the top quantity field. Note that the bottom quantity will appear automatically and is calculated to be one year's expected demand. Enter Min Qty values in the next two lines which are evenly spaced among the top Min Qty and the Max Qty fields as shown in figure 4.

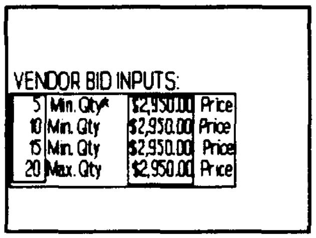

Figure 4. Quantity/price bid for vendor #1.

In this case enter the same unit price in all four price fields since vendor #1 offered no price breaks.

Step 3. Determination of optimal reorder point: Note the comment box. The risk warning should not be illuminated. It is necessary to lower the reorder level to achieve the required service level for this vendor. Iteratively lower the reorder level in the parameters section until the warning appears, then raise it by one unit. This revised reorder level should be 39 units.

Step 4. Determination of optimal lot size: Observe the vendor bid input fields (Figure 5). Note that in the upper row, the

VENDOR BID INPUTS

5	Min. Qty*	$2,950.00	Price	$67,558.05	Rel. Cost
10	Min. Qty	$2,950.00	Price	$68,643.16	Rel. Cost
15	Min. Qty	$2,950.00	Price	$70,093.08	Rel. Cost
20	Max. Qty	$2,950.00	Price	$71,663.03	Rel. Cost

Figure 5. Establishing the optimal lot size and preparing for printing.

vendor's minimum lot quantity has been entered. By raising this value by one unit, the expected total annual costs increases. Therefore, five is the optimal order quantity for this vendor. The order quantity should be returned to its original value. Because this optimum quantity is already in the uppermost quantity/price field, the worksheet is now ready for printing in WYSIWYG.

Step 5. Printing the data and analyzing results: Print the worksheet in WYSIWYG, ensuring that the system is properly configured for the printer to be used. The analysis section of the worksheet should appear as in Figure 6. Note that because the current inventory position is less than the reorder point, the initial order should be placed immediately for an order quantity of 24 units.

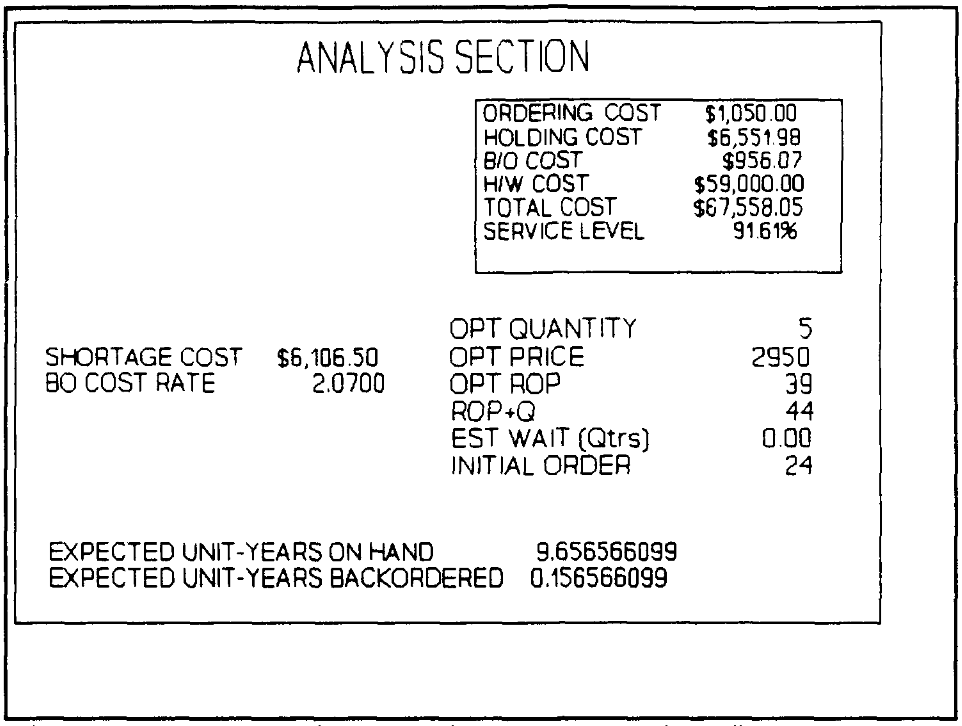

Figure 6. Analysis section for Vendor #1.

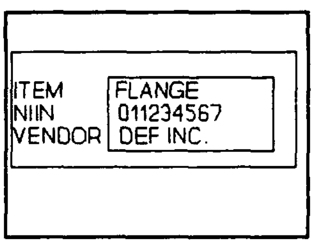

Figure 7. Nomenclature fields for vendor #2.

Step 6. Entering bid lead time and nomenclature for Vendor #2: The nomenclature details are shown in Figure 7. Update the bid lead time and nomenclature box for vendor #2 as shown in Figure 8. Reset the reorder level to the original value of 42 units.

Step 7. Entering price/quantity fields for quantity discount bids: Enter the minimum lot sizes for each price range in the quantity fields, starting with the smallest lot size. (If there are lot sizes larger than the total annual demand for the item, disregard them.) Enter the corresponding prices in the price fields, as shown in Figure 9.

60	Admin lead time (days)
76.5	Bid lead time (days)

Figure 8. Lead time for vendor #2.

Step 8. Determining the optimal reorder point: Because the lead time is greatly reduced for this vendor, the risk warning is not illuminated. Reduce the current reorder level in the parameters section until the risk warning appears. This should when the current reorder level is reduced to 9 units. Then raise it by one unit until the warning disappears. The optimal reorder level for this vendor is 10 units.

VENDOR BID INPUTS:

1	Min. Qty*	$3,500.00	Price
4	Min. Qty	$3,250.00	Price
11	Min. Qty	$3,000.00	Price
20	Max. Qty	$3,000.00	Price

Figure 9. Price/quantity entries for vendor #2.

Step 9. Determination of optimal lot size: The lowest unit price has a range from 11-20 units. Starting with the smallest lot size corresponding to this unit price, increase the lot size by one unit. Because it increases, return to the original value of 11 units. Proceed to the row having the next lowest unit price. Repeat the procedure with the next lowest unit price (having a range of 4-10 units). Notice that the smallest lot size is optimal for this unit price as well. Proceed to the row with the next lowest unit price. Finally, note that in performing the same process for the 1-3 unit price range, expected total annual costs for this range are minimized at a

Parameters:

5	Quarterly Demand
10	Current Reorder Level
20	Current Inventory Position
1	Essentiality
1	Avg. Units/Requsition
$750	Award Cost
$75	Delivery Order Cost
0.23	Holding Cost Rate
0.1	Target Risk

Figure 10. Parameters section reflecting revised reorder point for vendor #2.

lot size of 2 units. An examination of the three minimum total cost values appearing in the Rel. Cost fields for the three price breaks reveals that the lowest expected total annual cost is achieved by ordering in lot sizes of 11 units. This is therefore the optimal order quantity for this vendor. Enter this value with its corresponding price in the uppermost quantity/price fields as shown in Figure 11. The worksheet is now ready for printing.

VENDOR BID INPUTS:

11	Min. Qty*	$3,000.00	Price	$66,948.73	Rel. Cost
4	Min. Qty	$3,250.00	Price	$70,426.16	Rel. Cost
11	Min. Qty	$3,000.00	Price	$66,948.73	Rel. Cost
20	Max. Qty	$3,000.00	Price	$69,903.56	Rel. Cost

Figure 11. Vendor bid data box ready for printing.

The analysis section should contain the data shown in figure 12. Note that because the reorder point has been reduced to a value less than the current inventory position, the analysis section recommends that the procuring agency should wait two quarters before issuing the first delivery order. This is the estimated time it will take for the inventory position to be reduced to the revised reorder point of 10 units.

Step 10. Bid comparison: Vendor #2 is the superior bidder. His expected total annual costs value is $66,948.73 while vendor #1 has a value of $67,558.05. Although this vendor's

ANALYSIS SECTION

ORDERING COST	$886.36
HOLDING COST	$5,884.74
B/O COST	$177.63
H/W COST	$60,000.00
TOTAL COST	$66,948.73
SERVICE LEVEL	92.08%

		OPT QUANTITY	11
SHORTAGE COST	$6,210.00	OPT PRICE	3000
BO COST RATE	2.0700	OPT ROP	10
		ROP+Q	21
		EST WAIT (Qtrs)	2.00
		INITIAL ORDER	11

EXPECTED UNIT-YEARS ON HAND	8.528604384
EXPECTED UNIT-YEARS BACKORDERED	0.028604384

Figure 12. Analysis section for vendor #2.

unit price is higher, the expected total annual costs are reduced by this vendor's ability to reduce procurement lead time. If this bid is within the realm of affordability in terms of procurement costs, and barring any other exclusionary factors, the contract should be awarded to vendor #2.

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